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MULTI-HAZARD SCENARIOS:

Participatory processes for more resilient communities and territories

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Summary

“Resilience (...) is about having the capacity to continue to learn, self-organize, and develop in dynamic environments faced with true uncertainty and the unexpected, like steering a vessel in turbulent waters" (Folke 2016)

Abstract

The thesis aims to understand how participatory urban planning can foster the transformative resilience of territories and communities in response to natural disaster risks. This research is based on the premise that the integrated use of participatory planning tools and decision-making support systems, when capable of mediating dialogue between technical knowledge and citizen science, represents a promising strategy for strengthening territorial resilience and positively contributing to the enhancement of social capital. In this context, the goal is to promote greater preparedness of the actors involved through knowledge sharing and shared responsibility across all phases of the disaster management cycle. The innovation of this research lies in the adoption of a multidisciplinary approach that integrates citizen science with design principles, geospatial sciences, geographic information technologies (Geodesign), and the assessment of natural risks and specific vulnerabilities — physical, social, and environmental — in urban projects and policies. Based on this integration, a tool was developed to enable effective, rapid, and democratic collaboration among the various stakeholders involved in strategic planning processes. The expected outcome is that the tool will guide collaborative territorial and urban projects toward the development of scenarios focused on resilience to natural disasters and climate change, grounded in informed and inclusive decision-making. Additionally, it is expected to strengthen social capital by fostering the creation or reconnection of community networks in the co-construction of norms, values, and spatial practices that reflect the diversity of ideas, social conditions, and beliefs within a given society, thereby enhancing mutual trust among citizens and with public institutions. The tool was applied to the case study of Camerino, addressing its social, environmental, and economic vulnerabilities while recognizing crises as opportunities for transformation, guiding long-term development scenarios from a more resilient perspective. The results highlighted the development of context-sensitive proposals aligned with disaster resilience objectives, as well as a more solid and democratic integration between local knowledge and technical planning approaches, facilitated by the use of the tool. An increase in community engagement was also observed, with new proposals for participatory projects based on Geodesign emerging from the workshop participants. However, a key limitation of the study is that, despite the professional diversity of participants, it remained confined to the university environment and involved mostly individuals affiliated with the institution. Further development of the research requires a reconfiguration of participant selection, including representatives from different sectors of the community, the involvement of public administration, and a balanced representation in terms of age, gender, social class, and educational level.

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Introduction

We entered the 21st century facing the challenges caused by the development model inherited from the previous century. Following a series of catastrophes with unexpected death tolls, infrastructure damage, and disruptions to livelihoods on a global scale, the international community recognized—albeit belatedly—that humanity is confronted with an unprecedented global threat. These natural disasters and their impacts on communities and territories constitute the central theme and starting point of this research.

The premise adopted here is that climate change and rapid urbanization - both direct consequences of the 20th-century production and consumption model, with projections of continued growth in the present century - have significantly increased the exposure of populations and infrastructure to natural hazards. With the advent of industrialization, the intensive use of fossil fuels and natural raw materials has produced harmful effects on the atmosphere, particularly in raising global temperatures. This process has contributed to the intensification of climate cycles, altering precipitation patterns, which in turn increases the frequency and magnitude of natural events with hazardous potential. This scenario highlights the need to develop new strategies to address the growing impacts of these threats, both in terms of their recurrence and the scale of the damage they cause. At the same time, industrialization triggered mass migration from rural areas to urban centers, which now house more than half of the world's population. This rapid, often unplanned urbanization has resulted in the concentration of people and infrastructure in vulnerable areas, exacerbating exposure to natural processes - particularly among economically disadvantaged groups.

It is important to highlight that natural hazards are naturally occurring events with the potential to cause damage and losses to societies and the environment (Kusumastuti & Viverita, 2012), becoming disasters when populations or infrastructure are affected. Measuring disaster-related damages is inherently challenging, and such losses can never be quantified in absolute terms. However, between 2005 and 2014, estimated losses amounted to approximately 76,424 lives and 65 billion dollars (UNISDR, 2016). Data from EM-DAT for the past decade (2014–2024) indicate a decrease in the number of fatalities, but an increase in economic damages compared to the previous decade. These figures suggest that government and community preparedness efforts have contributed to reducing disaster-related mortality, even as the frequency and magnitude of such events continue to rise.

Many scholars attribute the reduction in mortality rates to the impact of Disaster Risk Reduction (DRR) policies, initiated in the 1990s. That decade was designated as the "International Decade for Natural Disaster Reduction," emphasizing the importance of creating mechanisms aimed at mitigating disaster risks. In 2005, the World Conference on Disaster Reduction, held in Kobe, developed the Hyogo Framework for Action 2005–2015, an international agreement signed by 168 member states that established guidelines for global disaster risk reduction, introducing resilience both as a response and as a long-term goal. Upon its conclusion, the agreement was reaffirmed through the Sendai Framework (2015), which aligned more closely with global agendas, highlighting the interconnection between disasters, climate change, and sustainable development. The document outlined four key priorities: understanding disaster risk, strengthening governance, investing in disaster risk reduction, and enhancing preparedness for effective response.

The principle of subsidiarity, recommended by the European Union since 2015, establishes that public decisions and actions should be taken at the lowest level closest to the affected populations, provided that this level has the capacity to act effectively. In alignment with the guidelines of the Sendai Framework, resilience is proposed through a community-based approach, which requires not only an understanding of risk factors but also of the intrinsic and specific vulnerabilities of each territory and society, as well as their response capacities (Ran et al., 2020). A community's response capacity is influenced by its environment, economic conditions, and individual beliefs (Helsloot et al., 2004). Therefore, effective response mechanisms must integrate factors related to infrastructural, environmental, economic, social, and cultural vulnerabilities.

Despite its complex and multifaceted intellectual foundations, resilience has frequently been conceptualized and operationalized through three distinct yet interconnected capacities: conservative coping adaptation, incremental reformist adaptation, and fundamental transformative adaptation (Asadzadeh et al., 2022). The interlinkage between disaster risk reduction policies, environmental and climate policies, and sustainable development - particularly since 2015 with the launch of global agendas - alongside growing awareness of the unpredictability of disasters, has led to an evolution of the concept toward co-evolutionary resilience or, in other words, transformative resilience (Asadzadeh et al., 2017). In this sense, resilience is increasingly understood as a catalyst for the transformative potential of cities - a dynamic concept that transcends mere absorptive capacity to encompass processes of adaptation and structural transformation within urban and territorial systems. Resilience is thus no longer viewed merely as the antithesis of vulnerability, but rather as a comprehensive framework aimed not only at the prevention and management of unexpected events, but also at promoting improvements in the environmental and social quality of territories (Brunetta et al., 2021). Transformative resilience, in this context, is defined by the ability of territorial systems to respond systemically and dynamically to emerging global challenges through non-linear transformation processes. These processes involve both natural and anthropogenic components of territorial systems, influencing their performance, quality, and functions. The transformative perspective of resilience therefore calls for a paradigm shift in urban studies, one that focuses on reconfiguring existing institutional structures, spatial arrangements, and governance mechanisms to enable more sustainable and resilient development trajectories. This perspective frames disaster as a “window of opportunity,” in which investments in social and economic capital for reconstruction are redirected toward Building Back Better or a genuine ecological, green, and digital transition.

Interconnected urban systems are entangled with complex and layered socio-ecological risks, which transformative resilience planning aims to address (Twigg, 2015). This context calls for innovative approaches and structurally transformative pathways that bridge traditional knowledge (such as citizen science) with technical and scientific disciplines, framed within a holistic and multi-hazard perspective. While academic research has attempted to fill this gap, its translation into empirical practice remains limited. Participatory initiatives have largely concentrated on localized risk mapping, the establishment of early warning mechanisms, or public assemblies convened to review already finalized projects - typically centered around a single hazard. However, such approaches often fall short in fostering long-term civic engagement and collective agency, resulting in isolated actions disconnected from systemic transformation.

The evolution of resilience-oriented frameworks in the field of disaster risk reduction has generated an extensive discourse around the multiplicity of concepts and assessment methodologies, both at the territorial level (including urban planning, architecture, engineering, ecology, geology, and geography) and at the community level (drawing from sociology, urban studies, and psychology). Although there has been a proliferation of indicator-based evaluation models, a shared framework remains elusive: there is no agreement on which metrics to adopt, the appropriate spatial scales, modes of representation, or the strategic purposes they should serve. Leading scholars such as Cutter and Derakhshan (2019) underscore the lack of robust empirical validation of these frameworks, most of which remain confined to academic experimentation. Moreover, the absence of a clear linkage between measurement tools and concrete policy interventions often renders such indicators ends in themselves, rather than means to guide action. To overcome this disconnect, the integration of technical knowledge into planning and governance processes must be pursued through urban policy, with particular attention to the local scale, where adaptive and participatory capacities are more effectively mobilized.

Urban planning has the capacity to reduce vulnerabilities related to exposure and land use but also plays a fundamental role in creating long-term scenarios for the sustainable development of cities and territories (Debnath et al., 2022), as well as in listening to communities and translating their concerns into design proposals. Thus, the concept of disaster resilience has been contextualized within urban disciplines to address concerns about urban development in the face of risks and future uncertainties, enhancing resilience levels and adaptive capacity (Shipper and Pelling, 2006).

But how can scientific and technical knowledge be integrated with Citizen Science in urban planning? Numerous participatory project proposals have been utilized at the local level for urban projects. Their positive aspects include raising public awareness of the reasons behind decision-making, thereby sharing the responsibility of urban development between the public authorities and the community; ensuring access to information and learning, leading to a more transparent process and a better prepared population for emergencies; and fostering a more equitable process where all city sectors have the opportunity to contribute equally. Among the challenges and limitations, difficulties in integrating technical expertise into participatory processes are frequently observed, particularly due to the complexity of specialized language. A further obstacle is the lack of trust in public authorities and community representatives, whether stemming from political disagreements or the ineffectiveness of previous participatory initiatives. Additionally, many processes are marked by insufficient information and civic capacity, leading to ineffective outcomes when communities do not fully understand the scope of the project or lack the critical tools necessary for meaningful engagement (Angelini and D'Onofrio, 2014). These limitations are compounded by the difficulty of engaging relevant stakeholders and, more critically, by the absence of community leadership and networks with experience in decision-making systems, particularly in localities characterized by low social capital (Nagawaka and Shaw, 2004). Participatory processes should not only serve to inform citizens for conscious decision-making but also foster the co-production of knowledge - preparing communities for the possibility of future disasters by integrating lessons learned from past experiences and promoting the creation or reconfiguration of social networks and normative frameworks. Only through such an approach can one truly speak of community resilience, grounded in a deep understanding of the specific vulnerabilities, aspirations, and potentialities of each territory and society.

Another crucial aspect is the integration across sectors and levels of governance. If the participatory process succeeds in fostering the exchange of knowledge and information among all local actors and enhances the preparedness of local governments and communities, this knowledge must be transferred to higher levels - regional, national, and international - to ensure the availability of specific and detailed data at each spatial scale (Komendantova et al., 2013; Imperiale and Vanclay, 2020). Regional policy and planning, for instance, should be informed by a consolidated body of municipal-level data within the regional territory, rather than by the indiscriminate replication of international frameworks that fail to account for local specificities. The same principle applies vertically, from regional to national, and from national to international levels. This integration, however, requires the harmonization of data and indicators, supported by agreements that ensure consistency from the adopted definition of resilience to the specific methodologies used for measuring each indicator.

Horizontal coordination among governmental sectors at all institutional tiers is equally necessary. In urban planning, for example, where government responsibilities are typically divided into distinct administrative levels, it is inconceivable that a project might succeed without articulation and cooperation among departments operating at the local, regional, and national scales. At the international level, aligning diverse policy agendas is also essential. Resilience cannot be meaningfully addressed without its interconnection to sustainable development and adaptation of climate change. Furthermore, from a multi-scalar perspective, research methodologies must be adapted to each specific geographical level. This implies that resilience and vulnerability indicators differ across scales, as do the stakeholders involved, the systems under analysis, and ultimately, the scale and scope of the projects themselves.

This thesis presents a reflection on the role of participatory co-design in the pursuit of transformative resilience to multiple hazards at both local and regional levels. By integrating the various perspectives discussed throughout the research, the work culminates in the development of an instrument - REMAP (Resilient and Engaged Multi-hazard Assessment for Planning) - designed to facilitate the integration of technical expertise and local knowledge in support of urban planning decisions aimed at enhancing resilience to natural disasters. The instrument was applied to a case study: the city of Camerino (MC), generating a long-term urban resilience scenario that was thoroughly discussed by a diverse group of actors with varying professions, backgrounds, cultures, aspirations, and knowledge systems.

The case study highlights the specificities of the study area, as even before experiencing the severe effects of the seismic events of 2009, 2016, and 2017, Central Italy - and particularly its inland areas - had already exhibited a concerning series of negative demographic and socioeconomic trends, stemming from its own structural characteristics and identity. Moreover, the entire country was still recovering from the 2008 financial crisis when the sequence of disasters occurred, and just as the first signs of post-earthquake recovery emerged, a global health crisis further slowed reconstruction plans and efforts, extending social and financial challenges as well as recovery timelines. The overlap of these events and the increasing complexity of risk management - where risks are progressively interconnected or intertwined - underscores the need for interdisciplinary action plans that consider both the vulnerability of territories to the multiple hazards they face and their potentialities, interpreting physical and social reconstruction as an opportunity for the development of inland areas and guiding the ecological, economic, and digital transition.

Problematic context

In 2023—the last year with complete data available in EM-DAT at the time of writing—399 disasters associated with natural hazards were recorded. These events resulted in 86,473 deaths and affected 93.1 million people, generating economic losses of approximately USD 202.7 billion. The earthquake that struck Türkiye and Syria in 2023 was the most devastating of the year, both in terms of loss of life and financial damages, with 56,683 recorded deaths and estimated damages of USD 42.9 billion. This disaster impacted approximately 18 million people across the two countries, making it the second most significant event in terms of the number of individuals affected. Despite being a high-magnitude event (7.8 on the Richter scale), the region's socioeconomic, political, and humanitarian conditions—exacerbated by the prolonged conflict to which the country has been subjected—were largely responsible for its destructive impact. The earthquake struck a country with fragile and largely destroyed infrastructure, where a displaced population was already living in shelters, facing difficulties in international coordination and humanitarian aid, and suffering from a lack of resources. Similarly, the case study presented in this research is characterized by a succession of natural and anthropogenic disasters. Central Italy is currently undergoing a recovery process following a large-scale seismic sequence that occurred in 2016. The impact of the earthquake was exacerbated by previous events, such as the 2008 financial crisis, as well as by subsequent occurrences, notably the COVID-19 pandemic starting in 2019. Additionally, the region is experiencing processes of depopulation and population aging, accompanied by the consequent loss of essential services.

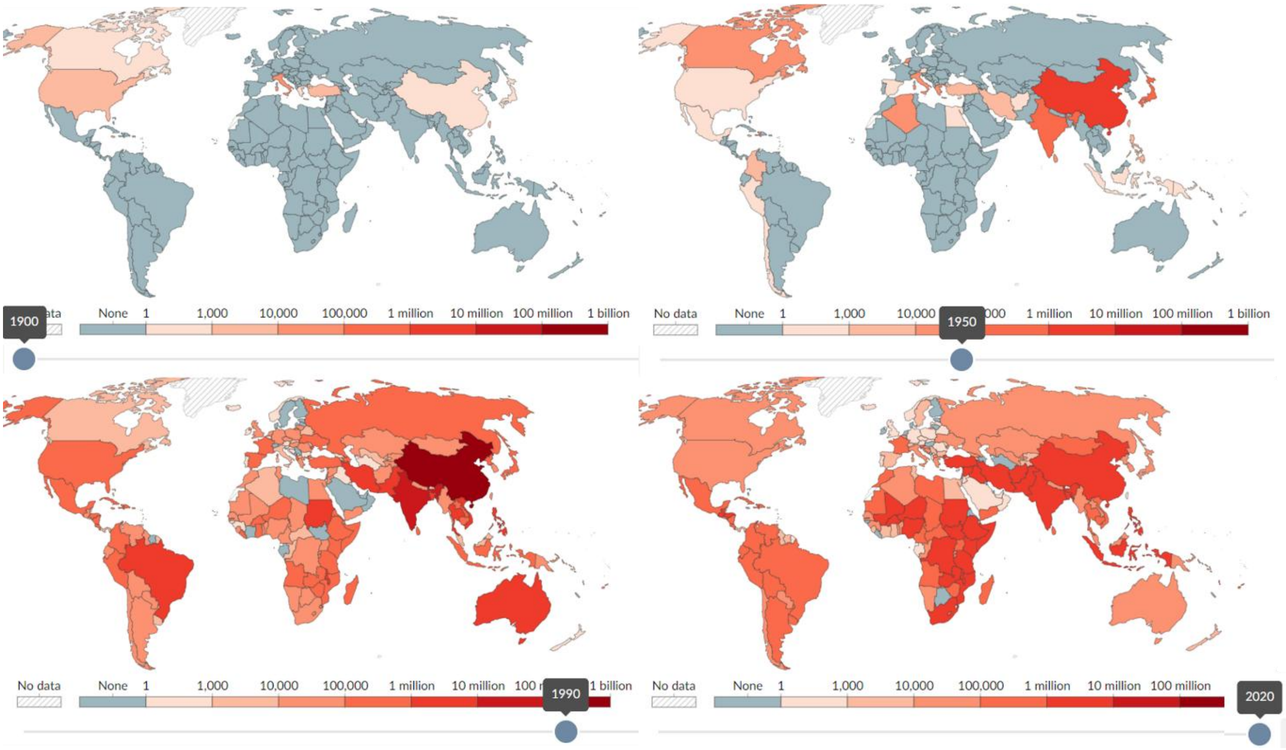

Figure 1: Decadal average: Annual number of people affected by disasters. Source: https://ourworldindata.org/natural-disasters

This study was therefore designed to investigate how to strengthen resilience in the context of multiple disasters and specific vulnerabilities. But what role does urbanism play in fostering resilience? The study of Disaster Risk Reduction (DRR), in connection with urban planning, is intrinsically linked to the themes of vulnerability and resilience, presenting the challenge of restoring balance to territorial systems affected by different types of disasters and exposed to environmental, social, and economic vulnerabilities. The academic literature highlights two main approaches through which urban planning can contribute to disaster risk reduction. The first focuses on urban design, emphasizing the improvement of physical infrastructure and the search for risk mitigation strategies, such as nature-based solutions or large-scale engineering projects. This includes the development of resilience plans that support ecological and energy transitions, among other similar initiatives. The second approach is directly related to territorial governance, addressing how collective decision-making processes can influence post-disaster reconstruction and the promotion of resilience.

The literature on the first approach is extensive and well-documented. However, for the second approach, scientific studies have not been sufficiently implemented or complemented by the practical experiences of governments at various levels, which weakens community responses and the shared responsibility for decision-making. Many vulnerability/resilience assessment tools based on indicators have been developed at the academic level but have not undergone practical experimentation (Cutter and Derakhshan, 2019). Practical and participatory experiences related to DRR remain largely confined to universities and typically address only a specific hazard. In such cases, participation is often limited to data collection (through surveys or community mapping) or voting on predetermined issues. In recent years, participatory processes for climate adaptation plans have emerged, driven by initiatives such as the 100 Resilient Cities program. However, the design perspective at the urban level remains focused primarily on reducing carbon emissions, working particularly on systems such as urban greenery and mobility.

The existing tools supporting decision-making processes are highly complex, deriving from mathematical models such as decision support systems, agent-based modeling (ABM), multi-criteria modeling, and Delphi methods. The technical language barrier hampers communication, and as a result, outcomes remain confined to academics and municipal technicians—each within their own sector—leading to top-down information processes in which pre-developed proposals are presented to the population merely for approval or rejection through public assemblies, participatory budgets, discussion groups, and workshops. Regarding participatory tools, most processes rely on overly simplified methods such as surveys, interviews, basic mapping exercises, and the widely used post-it boards. This linguistic and methodological diversity has created a dichotomy between the responsibilities of the technical sector and the community, where processes are developed by the "competent sector" and merely assessed, validated, or selected by the general public.

Listening methods alone do not create dialogue! A participatory process must be an exchange of experiences and knowledge, allowing the community to understand the objectives and the means to achieve them while also serving as a learning tool for local authorities. This includes leveraging the expertise and experience of local actors, particularly regarding previous disasters. Some methodologies capable of fostering such integration are based on negotiation-oriented proposals, such as Geodesign, a tool that integrates technical complexity, GIS visualization, and community participation in the discussion and negotiation of planning proposals. Geodesign uses GIS tools to integrate project proposals and plans with rigorous negotiation criteria, ensuring a more democratic decision-making process. However, Geodesign still lacks significant studies focused on multi-hazard resilience. The introduction of GIS (Geographic Information Systems) has represented an opportunity to merge these perspectives, ensuring that the technical complexity of urban planning can be presented in a way that is accessible to the public. GIS-based tools can process complex statistical calculations and translate them into simple visualizations. This capability has facilitated effective communication within participatory design processes, enabling communities to understand and form opinions on projects still in development or even contribute to data collection that serves as the foundation for planning. For this reason, the most recent decision-support tools are derived from these systems.

In light of the aforementioned considerations, this research emerges from the perspective of transformative resilience to multiple risks, with the objective of developing a participatory tool for decision-making in urban projects that takes into account physical, environmental, social, and economic vulnerabilities. The complexity of managing an overwhelming amount of data related to the various risks and vulnerabilities faced by a community or territory has exceeded human capacities within reasonable timeframes, necessitating the use of digital tools. Initially, the research considered the development of Decision Support Systems (DSS) to guide participatory decision-making. However, the cognitive demands of these systems - whose construction is complex and whose assimilation is even more challenging for the general public - have led to a disconnect between technical work and public participation.

Several gaps persist, which this study aims to address and propose potential solutions for, though these largely depend on factors beyond our capacities as researchers. The first gap relates to the global challenge of interconnecting policies and plans across different sectors that are intrinsically linked, such as disaster risk reduction, environmental policies, climate change mitigation, and sustainable development. Similarly, at the national and regional levels, there remains a pressing need to develop laws and action plans that simultaneously provide a foundation for baseline plans - such as reconstruction plans and climate adaptation plans - so that lower levels of governance do not have to start from scratch with each new disaster, thereby accelerating recovery processes. At the same time, there is a need to integrate bottom-up policies that consider the specific characteristics of each territory and community.

The second gap concerns ensuring that participatory planning is democratic, transparent, and that community proposals are considered and carried through to completion, regardless of potential political changes, thereby increasing trust in public administration. The third gap is related to the existence of and access to databases, as well as the lack of integration between them. There is a pressing need for the integration of different platforms and the standardization of which data should be presented and how they should be displayed, facilitating the integration of resilience studies across different geographic areas and enabling comparative analyses. The ability to compare data ensures that resources from higher levels of government are distributed more effectively.

A centralized government model that works in a disconnected way

At a global level, significant progress has been made, with 2015 marking a milestone for policies in the fields of sustainable development (Agenda 2030), disaster risk reduction (Sendai Framework), and climate change (Paris Agreement), all declared in the same year. Authors such as Schipper and Pelling (2006) state that the expected outcome of a development policy includes an improvement in living standards, defined by economic and social progress, which helps reduce disaster risk by increasing people's ability to prepare for, cope with, and recover from disasters. However, the post-2015 agendas are still organized into separate intergovernmental processes, each addressing disaster risk (led by UNISDR), climate change (led by UNFCCC), and sustainable development (led by UNDP) (Cuaresma et al., 2018), despite efforts from the academic community to integrate them. This division leads to difficulties in interrelating related issues, such as environmental preservation, global warming mitigation, and disaster risk reduction.

At the national level, the literature review highlights the importance of a government that can centralize efforts, manage disaster reduction and reconstruction processes, while also being able to delegate the responsibility of emergency management and reconstruction to regions and/or municipalities. This would allow for the creation of locally based policies that foster preparedness processes through the participation of all stakeholders. In the Italian case, Salvi (2019) argues that following the 2016 seismic sequence, the absence of coordination on shared objectives with the central government and other regions resulted in resources being inadequately distributed across different regions. The author emphasizes the lack of a national economic and social recovery plan for a vast interregional area with structural homogeneity and fragility: Central Italy.

Italian scholars such as Salvi (2019) point to the absence of a national law or strategy for disaster risk reduction and disaster management, as well as the lack of coordination on shared objectives between the central government and the regions. This situation delays recovery processes since the autonomy of regions and municipalities encourages the development of new strategies for each disaster individually, forcing local administrations to manage emergencies and initiate reconstruction without external support. There is a proliferation of strategies that do not always take into account past disaster experiences. In recent years, discussions have emerged regarding the development of a *Codice Nazionale della Ricostruzione*, whose draft was approved by the Council of Ministers in June 2013. The project, presented by the Minister of Civil Protection and Maritime Policy, Nello Musumeci, was also developed with the support of *Casa Italia*. The Code revises and innovates the entire post-disaster reconstruction system and aims to accelerate the reconstruction process by establishing a five-year timeframe (extendable to ten years), creating an extraordinary government commissioner for reconstruction, and setting up a dedicated fund and an interinstitutional coordination office for reconstruction.

Although disaster management remains centralized and no national law has yet been enacted for this purpose, the *Strategia Nazionale per le Aree Interne (SNAI)* and the *Piano Nazionale di Ripresa e Resilienza (PNRR)* have opened space for locally based policies, granting local governments greater autonomy in seeking resources. While not strictly a disaster risk reduction strategy, the SNAI seeks to alleviate the vulnerabilities of Italy’s remote areas and was a pioneer in locally based policies, delegating decision-making on resource allocation to regions and communities. Critics of this strategy argue that it is difficult to establish selection criteria for projects, as the generalized requirements fail to address the specificities of many regional contexts and exclude the particular realities of some cases.

The contradiction of non-participatory community resilience

Despite significant advancements in recent decades in the development of participatory policies aimed at disaster risk reduction (DRR), a fundamental contradiction persists between the pursuit of community resilience and the lack of active community involvement in planning and decision-making processes. Community resilience, as defined by Norris et al. (2008), is the outcome of processes that involve adaptive capacities, social cohesion, and local resources to cope with adversities. However, these capacities are often underutilized due to the exclusion of communities from strategic debates and risk management processes. This exclusion undermines the effectiveness of DRR plans, as centralized decisions tend to overlook local knowledge, cultural specificities, and the priorities of affected populations.

Studies such as Arnstein's (1969) seminal work on the "Ladder of Participation" emphasize that low or symbolic levels of participation—such as superficial consultation or mere information dissemination—fail to empower communities. Resilience, when constructed through a top-down approach, often not only fails to meet actual local needs but also fosters distrust toward responsible authorities. Participatory approaches enable resilience to be understood as a shared process in which community involvement contributes to disaster preparedness, response, and recovery (Cretney, 2016). The absence of active participation also limits the potential for social learning, where communities, alongside experts and managers, can develop innovative solutions tailored to their specific realities. This participatory gap reflects a technocratic vision of resilience, which prioritizes structural interventions—such as infrastructure and technology—over human-centered approaches.

The contradiction becomes even more evident in contexts where resilience policies are implemented without adequate consultation or involvement of affected communities. For example, relocation initiatives in high-risk areas often fail because they do not consider local social and economic dynamics, leading to the displacement of vulnerable populations and exacerbating inequalities (Adger, 2000; Cutter et al., 2003). Therefore, achieving genuine community resilience requires not only the formal inclusion of communities in DRR processes but also the recognition and amplification of their voices as central elements in decision-making. Tools such as participatory methodologies and the use of collaborative technologies, such as georeferencing systems, can help bridge this contradiction, promoting the democratization of the planning process and leading to more sustainable and adaptable outcomes.

The lack of an integrated multi-risk perspective

One of the significant challenges in disaster risk management is the absence of plans and policies that integrate the complexity of the multiple risks to which territories and communities are exposed (Galderisi and Limongi, 2021). The literature review highlights that risks are often addressed in isolation, ignoring their interactions and cumulative effects, which undermines the effectiveness of mitigation and resilience strategies (Ward et al., 2022).

However, addressing the interconnected relationships that influence complex systems, such as urban or territorial systems, requires a holistic perspective, which is inherently difficult to achieve. Prominent authors such as Fritjof Capra and Pier Luigi Luisi (2014) and Norris et al. (2008) refer to Aristotle's famous phrase, "The whole is greater than the sum of its parts," to illustrate how different life systems should be analyzed, ensuring that the existing interconnections between systems and within a system itself are not ignored. Capra and Luisi (2014) emphasize that our educational and academic system has evolved from Cartesian science and the idea of subdividing content into the smallest possible parts to achieve the highest level of detail and specialization. This subdivision of a whole into parts neglects the influence that each part exerts on the others. In the case of community resilience, Norris et al. (2008) argue that a collection of resilient individuals does not guarantee a resilient community: "People in communities are resilient together, not just in similar ways" (Brown and Kulig, 1996/97).

Based on this premise, the study of territorial systems should not be conducted by subdividing vulnerabilities and risks into increasingly smaller components and assimilating results without analyzing their relationships and the influence they exert on one another. Similarly, resilience cannot be achieved by analyzing each risk in isolation. Cartesian approaches to DRR hinder the understanding of an adaptive perspective. The theory of complexity, developed by authors such as Morin (2008), provides a framework to comprehend how urban and socio-ecological systems function in interdependence. Complexity is inherent to systems where elements interact dynamically and adaptively, producing outcomes that cannot be reduced to the sum of their parts. In the context of multiple risks, these interactions often create "cascading effects," where an initial event triggers a series of secondary disasters. A classic example, linked exclusively to the physicality of natural disasters, is the 2011 Fukushima earthquake and tsunami, which resulted in a nuclear crisis, underscoring the need for an integrated approach.

However, the theory of uncertainty, as outlined by authors such as Knight (1921) and later expanded by Beck (1992), emphasizes that not all risks can be predicted or quantified, further highlighting how modern risks are globalized and amplified by economic and technological interconnections. In the context of natural disasters, this uncertainty is exacerbated by climate change, unplanned urbanization, and the interaction between natural and human-induced disasters. Uncertainty extends beyond the probability of events and includes unknown or unpredictable interactions between different risks. In the study of this research, the COVID-19 pandemic represents an example of an unforeseen risk. Both the pandemic and climate-related disasters highlight the global nature of certain risks to which we are exposed as a highly interdependent society. This interdependence underscores the urgency of an approach that recognizes risks not as isolated events but as systemic processes requiring global solutions.

The lack of an integrated perspective on multiple risks has significant practical consequences. Strategies that focus solely on a specific risk often underestimate cumulative impacts or interactions between different threats. For example, flood management policies that do not consider the impacts of subsequent droughts may inadvertently create new problems related to water resource management.

Integrating a multi-risk perspective requires a paradigm shift in territorial planning and management. Policies must acknowledge the inherent uncertainties of the planning process, adopting principles from complexity theory to address adaptive systems and flexible strategies that can be adjusted in response to emerging information. Interdisciplinary approaches should be adopted, combining quantitative and qualitative analyses. The large volume and complexity of data require the use of processing technologies such as machine learning, IoT, and artificial intelligence. A theoretically less recent but certainly more practical update within the public sphere is the use of geospatial models to map vulnerabilities and simulate impact scenarios. The use of GIS software enables complex calculations while delivering simple visualizations.

The Multi-Scale Challenges of Resilience to Natural Disasters

Perhaps the greatest gap in the literature connecting governance, resilience to natural hazards, and urban planning is linked to the multiplicity of scales and the lack of interconnections. The need for communication across sectors is imperative and is a recurring issue in each of the topics addressed in this work. In the definition of risks, there is a lack of integration between different types of risks and an understanding of their interrelationships in terms of causes and effects. In defining key concepts such as disaster and resilience, there is still no single definition that applies across all scientific disciplines—an effort that has been ongoing for over 40 years without success. In the field of resilience planning, there is a missing integration of physical, environmental, social, and economic perspectives that govern the social ecosystem. In governance models for risk management and the design of resilient cities, there is a lack of coordination between local, regional, and national authorities. In risk data collection, there is an absence of integration between databases at the same organizational level, which would enable data structuring at higher levels.

While there is a recognized need to act locally while thinking globally, there is also concern about national plans that integrate and guide local initiatives. Discussions oscillate between subsidiarity and horizontal coordination. The reality is that communication is lacking at all scales. There is a lack of exchanges, interconnections, and interrelations. A holistic, systemic, and complex analysis of the whole is missing. Daring to think about resilience in complex systems such as cities, territories, and communities requires a continuous process of expanding and narrowing ideas, objectives, and goals—paradoxically mirroring vital processes like breathing.

Defining the research question

This research began in 2021, after a delay of approximately six months due to mobility restrictions during the COVID-19 pandemic. That year, the Reducing Risks of Natural Disasters (REDI) Consortium proposed the study of epidemics like this one and their impact on the resilience of communities and territories. This became the first topic investigated, in an attempt to answer the pressing question of what impact the pandemic would have on cities and how territories could overcome its devastating effects on the economy, migration processes, working conditions, and, ultimately, a range of issues marked by uncertainty regarding the evolution of the problem and the expected outcomes. For urbanism, common topics included social distancing, disparities in remote work experiences during lockdown, accessibility to open spaces, and more. Based on the work already carried out by the consortium, it was decided to classify the pandemic as a natural disaster. Consequently, the first bibliographic research on the subject revealed its connection to climate issues and how climate change is partially responsible for the spread of diseases.

In May 2023, the WHO declared the end of the pandemic and a return to normality. The research question then shifted from "What will cities be like after the pandemic?" to "How can we overcome the effects caused by the pandemic?" Through an analysis of everyday life, it became clear that the pandemic could not be treated as an isolated event and that its effects overlapped with the impacts of other disasters with continuous effects over time and space. If we consider the proposed study area, the pandemic’s effects overlapped with pre-existing territorial vulnerabilities dating back to the 16th century, which were further exacerbated during the period of Italian industrialization and have become increasingly evident over time. In addition, the long-term effects of the 2008 financial crisis, the 2009 earthquake, and, more significantly and devastatingly, the 2016–17 earthquake must also be considered.

Thus, the second year of the research focused on the study of multiple disasters and the correlation between different types of disasters and their effects. The main objective at this stage was to reflect on the role of urbanism in promoting the resilience of communities and territories in the face of multiple hazards. The role of the urban planner is often confused with that of the decision-maker. It is essential to distinguish urban planning as a discipline responsible for the development of plans and public policy strategies from its role in land-use management. Regardless of the approach adopted, the urban planner should act as a facilitator, a listener, and a “translator” of the community’s aspirations within the design process.

From this perspective, the field of urban studies frequently examines governance models and decision-making processes, and more recently, it has sought to incorporate co-design and participatory processes into its contemporary practices. Guided by the Sendai Framework, this research has focused on understanding how participation can enhance the preparedness of governments and communities to adapt to natural and anthropogenic risks, thereby increasing resilience levels. Participation also plays a crucial role in facilitating decision-making and negotiation processes, ensuring that choices are democratic and fair. In this context, the urban planner assumes the role of negotiation facilitator between different sectors and stakeholders, benefiting from both the technical knowledge of public administration and the local knowledge of the community to define the best options for resilient urban design, while also sharing responsibility for decision-making and outcomes.

Thus, the new research questions were reformulated as follows:

- How can the resilience of territories and communities to multiple natural disasters be enhanced?
- What is the role of the urban planner in fostering resilience?
- How can the resilience/vulnerability of a territory and a community be measured?
- How does participation contribute to preparedness?
- How can the effectiveness of participatory processes be ensured?

Contextualized, these questions can be summarized as: Can participatory urban design, seen as a tool for the preparedness of citizens and administrations, enhance resilience to natural disasters from a multi-hazard perspective?

The suggested hypothesis is that active community participation could support decision-making processes by bringing traditional knowledge into the discussion while, in return, receiving technical guidance, transparency, and information about processes, timelines, and policies related to resilience, adaptation, and sustainable development. To achieve this, a new methodology for participatory processes would be required - one that can inform and accelerate decision-making timelines, integrate the risk (and multi-hazard) perspective into existing public policies and urban projects, and translate technical language into a form of visualization accessible to all sectors of society.

Objectives and expected results

The main objective is to strengthen the adaptive capacity and resilience of territories and communities through participatory urban planning, promoting citizen preparedness and facilitating informed decision-making by public authorities. To this end, this study proposes the development of a guiding instrument for participatory processes, capable of bridging technical knowledge and citizen science, facilitating language and data visualization, and supporting the negotiation of proposals in a democratic format.

The expected outcome is that the tool will be able to guide democratic collaboration in territorial and urban projects, facilitating the integration and visualization of complex knowledge through simplified technical language. This would enable a better understanding of the current state of the intervention area and the visualization of the ideal scenario for transformative resilience in the face of multiple risks to which it is exposed. Such an approach would ensure an informed and democratic decision-making process through the engagement of multiple stakeholders, potentially contributing to the strengthening of social capital. Furthermore, the tool is expected to be capable of generating scenarios that integrate different disciplines and governmental sectors in a horizontal manner, promoting data sharing and institutional coordination. Additionally, it should be able to draw on diverse databases, ensuring that—even when originating from different sources—they follow a common methodological framework, thereby informing policies and plans at higher levels of governance with greater coherence and efficiency.

Research Methodology

The methodology of this research was structured around a systematic review of the scientific literature, with the aim of outlining the state of the art at the intersection of four main thematic axes: multi-hazard perspective, governance, multiscale interconnection, and resilience planning. This initial phase sought to identify theoretical and methodological gaps that could guide the development of the investigation. Foundational concepts such as transformative resilience (Holling, 1973; Norris et al., 2008; Brunetta and Caldarice, 2019), critical approaches to disaster management (Beck, 1992; Cutter et al., 2003), and governance (Torres-Lima et al., 2019; Karydi, 2025) were essential in constructing the theoretical framework that connects community resilience, participation, and geospatial tools (Campagna et al., 2016; Frigerio et al., 2016; 2019).

The research then proceeded to identify the risks to be studied, as well as their interrelations, causes, and effects, emphasizing the importance of a multi-hazard approach combined with an analysis of the intrinsic territorial vulnerabilities to enhance the resilience of complex systems to different types of disasters in uncertain contexts. Subsequently, a critical review of the concept of resilience was developed, acknowledging its ambiguity, semantic breadth, and multidisciplinary usage. The concept of vulnerability was also examined, with emphasis on current measurement methodologies and their practical application in public policies and projects.

Public policies were investigated across four administrative levels - international, national, regional, and local - highlighting the need for articulation between vertical and horizontal sectors. The theoretical reflection also addressed the role of community participation in enhancing disaster resilience, emphasizing its impact on strengthening social capital, preparing governments and communities, and sharing responsibilities in decision-making processes. In this regard, the research aimed to understand the challenges faced by participatory processes focused on building transformative resilience to multiple disasters, including: the disparity between technical and traditional languages; the degree of involvement of citizens, public administrations, and stakeholders; the interscalar challenges of information sharing between different levels of public administration; the fragmentation of interregional data systems; and the inaccessibility of digital platforms and the lack of data at the local level.

The central hypothesis of this research is that georeferencing tools (GIS), combined with participatory approaches based on negotiation - such as Geodesign - are capable of simplifying technical language and translating local knowledge into project proposals and public policies aimed at constructing future scenarios. The composition of these scenarios, based on predefined design systems, is intended to facilitate systems thinking and foster a vision of transformative resilience to multiple risks. Public participation in urban co-design processes is considered a catalyst for active citizenship and the strengthening of social capital, while also supporting consensus-building and the mutual exchange of technical-scientific and traditional knowledge.

To this end, the literature review provided the foundation for the development of a methodological instrument inspired by the Geodesign framework but aimed at offering a holistic reading of urban and territorial systems. This instrument seeks to promote higher levels of community and territorial resilience from a transformative perspective - that is, one that views overlapping disasters as opportunities to shift paradigms. The proposed methodology combines georeferenced analyses with participatory processes, enabling the mapping of vulnerabilities and the simulation of resilience scenarios across different territorial scales. The Geodesign framework (Steinitz, 2012) was adapted to meet the specific requirements of the study, structuring the stages into three main phases: representation, evaluation, and decision-making. GIS tools and the Geodesignhub platform were employed to operationalize the methodology, fostering the co-creation of urban solutions by professionals and local communities.

The resulting instrument was named REMAP (Resilient and Engaged Multi-hazard Assessment for Planning). REMAP was experimentally applied to a case study in order to test its functionality and evaluate its performance. The initially selected case study unit was the Central Italy crater area, later narrowed to the Macerata crater due to interregional data integration gaps. The documentary survey of the study area was based on bibliographic references concerning local vulnerabilities and on the quantitative analysis of social vulnerabilities using pre-selected indicators. Georeferenced data were collected and analyzed to map social, physical, and environmental vulnerabilities, using indicators from sources such as ISTAT and other regional databases. The territorial characterization included demographic analyses, critical infrastructure, and socioeconomic challenges. The assessment of social vulnerability was carried out using socioeconomic data processed with GIS software, involving data normalization and algebraic aggregation to generate thematic vulnerability maps in six dimensions: age, education, population density, housing quality, accessibility, and presence of foreign residents.

Following the redefinition of the study area, a new documentary review was conducted based on updated bibliographic sources, administrative documents, social media, and online news articles. This phase aimed not only to understand the specific vulnerabilities of the area but also to investigate local mechanisms of disaster response and recovery after the earthquake - whether these emerged from the community or exclusively from public administration - along with the participatory approaches implemented and the networks and norms established. Spatial and textual data were then organized into ten analytical systems, according to the Geodesign approach: green infrastructure, water system, agriculture, transportation, energy, settlements (housing), tourism, SMART, trade and industry, and cultural heritage.

The analysis followed the six models proposed by the Geodesign framework: representation model, process model, evaluation model, change model, impact model, and decision model. The first three models comprised technical analyses conducted by the author, while the last three were developed through a participatory process in the form of a workshop.

The workshop, entitled "*Camerino Workshop: Scenari condivisi per un futuro resiliente*", was conducted by the author with the facilitation of Professor Michele Campagna (University of Cagliari), and involved residents, municipal authorities, and experts in urban planning and risk management. Its primary goal was to co-create urban solutions to enhance the resilience of the city and its surroundings to the multiple identified risks. Following a guided tour of the historic center, participants collaboratively developed intervention proposals, assessing their impacts and feasibility using the Geodesignhub platform. The outcomes were synthesized into integrated proposals, offering practical solutions for strengthening territorial resilience. This collaborative process provided an opportunity to test the methodology in a real-world context, demonstrating its potential to engage multiple stakeholders in urban planning. During the workshop, the author also conducted a phase of direct observation, followed by an evaluation of REMAP by participants through a structured questionnaire.

The final stage of the methodology consisted of evaluating the results in light of the research questions and initial objectives. This analysis included the validation of the maps and scenarios generated, as well as an assessment of the participatory process's impact on decision-making. REMAP was evaluated in terms of its functionality, its capacity to simplify technical language, and its effectiveness as a democratic tool targeting multiple audiences. The evaluation also identified methodological limitations and suggested future research directions, with particular emphasis on integrating socioeconomic and environmental dimensions in resilient planning strategies.

Throughout all phases, the research maintained an interdisciplinary approach, integrating principles of urbanism, data science, and community participation. The proposed methodology, by combining geospatial tools with participatory processes, not only contributes to theoretical advancements in the field but also offers a practical framework to support the development of public policies and urban planning strategies in multi-hazard contexts.

Thesis structure

This thesis is structured into five main sections, organized to address the research questions and present the results in a logical and progressive manner. Each section has been developed to gradually build an understanding of the challenges, methodology, and proposed solutions related to resilience in multi-hazard contexts.

Introduction and Problematic Challenges: This section presents the research context, outlining the challenges associated with resilience in territories exposed to multiple risks. It defines the central problem, introduces the research questions, and describes the objectives and expected outcomes. Additionally, it outlines the research phases and provides a brief introduction to the methodology used, preparing the reader for the approach adopted throughout the study.

State of the Art on Disasters, Resilience, Vulnerability, and Governance: The first part provides a literature review on natural disasters, resilience, and vulnerability. It discusses key concepts such as the definition and classification of disasters, the relationship between climate change and disaster intensification, the concept of transformative resilience, and the challenges in measuring vulnerabilities and adaptive capacities. This section also highlights the need to integrate multi-hazard perspectives into resilience-oriented urban planning studies and practices. It further explores the historical evolution and contemporary models of disaster risk management, examining aspects of global, national, and local governance, with an emphasis on participatory processes and collaborative management models. International case studies, such as those of Japan, New Zealand, and Bangladesh, illustrate best practices and challenges. Finally, this section contextualizes the specific challenges faced in Italy, including institutional and cultural barriers as well as opportunities for innovation in resilience policies.

Development of REMAP: Based on the state of the art and similar experiences, REMAP was developed as a tool aimed at simplifying the co-design of development scenarios focused on resilience to natural disasters. This tool is designed to operate across multiple scales, facilitating the integration of technical language and *Citizen Science*, while also promoting the negotiation of proposals in a democratic manner.

Application of the tool: The case study of Camerino and the Macerata crater area (MC): The application of the tool was divided into two parts: the assessment of vulnerabilities at the regional level and the participatory co-design process for creating resilient scenarios for the city of Camerino and the Macerata crater area (MC). Initially, the study sought an application method for the tool that could encompass the entire *Cratere del Centro Italia* to understand the different impacts of the 2016 earthquake across various municipalities. The first phase of the tool focused on assessing the vulnerabilities and potentialities of inland areas in Central Italy, a region characterized by socio-economic challenges and high exposure to natural hazards. It analyzed demographic, economic, and historical trends, as well as initiatives such as the *Strategia Nazionale per le Aree Interne (SNAI)* and the *Piano Nazionale di Ripresa e Resilienza (PNRR)*. Due to difficulties in interconnecting data from different regions and the aim of working at the most local level possible, the practical application of the participatory process focused on the city of Camerino, in the Marche region. This section includes the characterization of the territory, an analysis of social and physical vulnerabilities, an assessment of ongoing projects, and the participatory workshop, where local technicians and residents collaborated in the creation of resilience scenarios. The results are presented as syntheses of resilient urban planning proposals.

Conclusions and Future Perspectives: The final part reflects on the achieved results, assessing the contributions of the research and identifying its limitations. It discusses the possibilities for practical application of the developed methodology and suggests directions for future research. This section also highlights the study's relevance for the formulation of public policies and more inclusive and resilient urban planning strategies. The structure of the thesis has been designed to guide the reader from a general introduction to the topic, through specific analyses and concrete proposals, culminating in critical reflections and recommendations for the future. This logical progression facilitates an understanding of the theoretical, methodological, and practical framework developed throughout the research.

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Part 01: The State of the Art on Resilience and Governance for disaster risk reduction

1.1 The Challenges of the 21st Century, Climate Change, and Disaster Risk

The past century witnessed the rise of the consumer society. In the 1980s, Beck, analyzing the consequences of industrialization and the dominant model of production and consumption, characterized the contemporary system as a “risk society” (Beck, 1986). He argued that modernity was undergoing a historical rupture, marked by a transition from the classical industrial model to an (industrial) risk society, in which the production of risks begins to outweigh the logic of goods production.

According to Beck (1986), the risk society is defined by a world of uncertainties generated by technological innovation and increasingly accelerated social responses. The emergence and dissemination of these risks shape a new global scenario, where uncertainties become non-quantifiable and exceed the traditional capacities of institutional control. This is an era of uncontrollability, as civilizational risks elude direct perception and are increasingly linked to physico-chemical formulas and scientific impacts that are not fully measurable. In contemporary times, risks not only intensify but also become market opportunities, structured by knowledge. As Beck (1986) notes, “the risk society is (...) also the society of science, media, and information. It thus reveals new oppositions between those who produce definitions of risk and those who consume them.” In this context, knowledge assumes a central role as the most significant intellectual product of modernity, as it is through knowledge that risks are identified, interpreted, and commercialized.

This dynamic is directly linked to economic models consolidated in the second half of the 20th century, which, on the one hand, promoted accelerated industrial development and enabled urban expansion, but on the other hand, deepened economic and social inequalities, increased poverty, and displaced large portions of the population to urban peripheries. These areas were occupied in an unregulated manner, resulting not only in various environmental problems but also in increased exposure to risks arising from natural hazards and processes (Sassen, 2014; Dickson, 2012). Moreover, these vulnerabilities are intensified by extreme events linked to climate change, which further exacerbate the impacts on these populations and territories (Canil et al., 2020).

Climate change is a complex and multidimensional long-term phenomenon that affects various aspects of the global climate - mainly precipitation patterns and temperature fluctuations - including the frequency and intensity of rainfall, the occurrence of droughts, the intensity of storms and cyclones, and rising sea levels due to glacier and polar ice cap melting. These changes have profound impacts on natural and human systems, threatening biodiversity, species survival, and the sustainability of urban systems (Pettorelli et al., 2021). Climate change is directly and indirectly related to the increasing frequency and severity of natural disasters and extreme events, exacerbating population vulnerability and intensifying the economic and social costs associated with these phenomena.

Forzieri et al. (2017) indicate that global warming is a major factor in amplifying climate risks, accounting for more than 90% of the increased risk to human populations, primarily due to the intensification of heat waves. Beyond direct effects—such as loss of life and infrastructure destruction—these impacts undermine livelihoods, exacerbate economic challenges (Berntell et al., 2024), and threaten food security (Dembedza, 2023). Furthermore, climate-related disasters can trigger severe psychological impacts, such as post-traumatic stress disorder (Dastidar, 2023), and facilitate the adaptation and spread of fungal pathogens and viruses, increasing the risk of epidemics and pandemics, as seen in the case of COVID-19, particularly among vulnerable populations (Seidel et al., 2024).

The intensification of storms, combined with rising sea levels, significantly alters coastal ecosystem biodiversity and affects soil microbiomes (Cao, 2023). Saltwater intrusion into coastal aquifers worsens water security challenges, impacting freshwater supply and leading to structural modifications in habitats, species redistribution, and alterations in ecosystem services.

Agriculture, one of the main economic drivers in many regions - especially in developing countries - is among the sectors most vulnerable to climate change. It plays a central role in determining progress or setbacks in the fight against poverty and in ensuring food security. However, adverse climate impacts - such as desertification, water scarcity, droughts, famines, crop failures, floods, pest infestations, and human and plant diseases - pose direct threats to food security and sustainable development. Moreover, species extinction and declining agricultural productivity may undermine poverty eradication efforts and pose significant risks to global economic growth. Efforts to mitigate climate effects often rely on unsustainable, polluting, and hazardous solutions, such as the intensified use of pesticides.

Climate change is a complex and multidimensional phenomenon that poses risks to multiple sectors and aspects of society through intricate interactions and feedback cycles involving geographic (spatial), ecological, political, sociocultural, and economic dimensions - all of which must be considered over time. This global crisis also exacerbates social and political challenges and is often referred to as the “mother of all conflicts” due to its links to rising violent disputes and civil wars, particularly in regions marked by high ethnic fragmentation. Studies indicate an increasing correlation between global warming, disasters, and security issues, with significant implications for both human and environmental safety. Population displacement caused by extreme weather events and natural hazards presents additional challenges to Disaster Risk Reduction (DRR) strategies and development efforts, as it increases the demand for policies addressing climate or environmental refugees. Finally, the inherent uncertainties associated with the phenomenon further complicate the environmental governance landscape, making it more difficult to implement effective and coordinated solutions (Munene et al., 2018).

The multidimensional and interconnected nature of climate change calls for a comprehensive and integrated approach, considering not only its physical and ecological impacts but also its social, economic, and political implications over the long term.

The recent COVID-19 pandemic highlighted global unpreparedness in dealing with health crises and reignited the debate on uncertainty regarding environmental and anthropogenic risks. It has led to a deepening of interdisciplinary studies linking public health, climate change, and urban planning. There is a growing perception that everything converges toward a common problem - even if not yet fully demonstrated - that climate change may also be responsible for the emergence and spread of certain disease variants.

Climate influences the transformation and alteration of both pathogens and human organisms (Murara and Aleixo, 2021). The same causes of climate change—such as pollution, globalization, and urban expansion—are also capable of increasing virus transmission and mortality risks. Natural disasters further impact the health and infrastructure sectors, overburdening healthcare systems. Thus, it can be said that these disruptions have environmental, social, and economic consequences both locally and globally, reinforcing existing territorial and community vulnerabilities. According to UNISDR (2012), disasters have nearly quadrupled in the last 40 years, and risks are becoming central issues in 21st-century daily life.

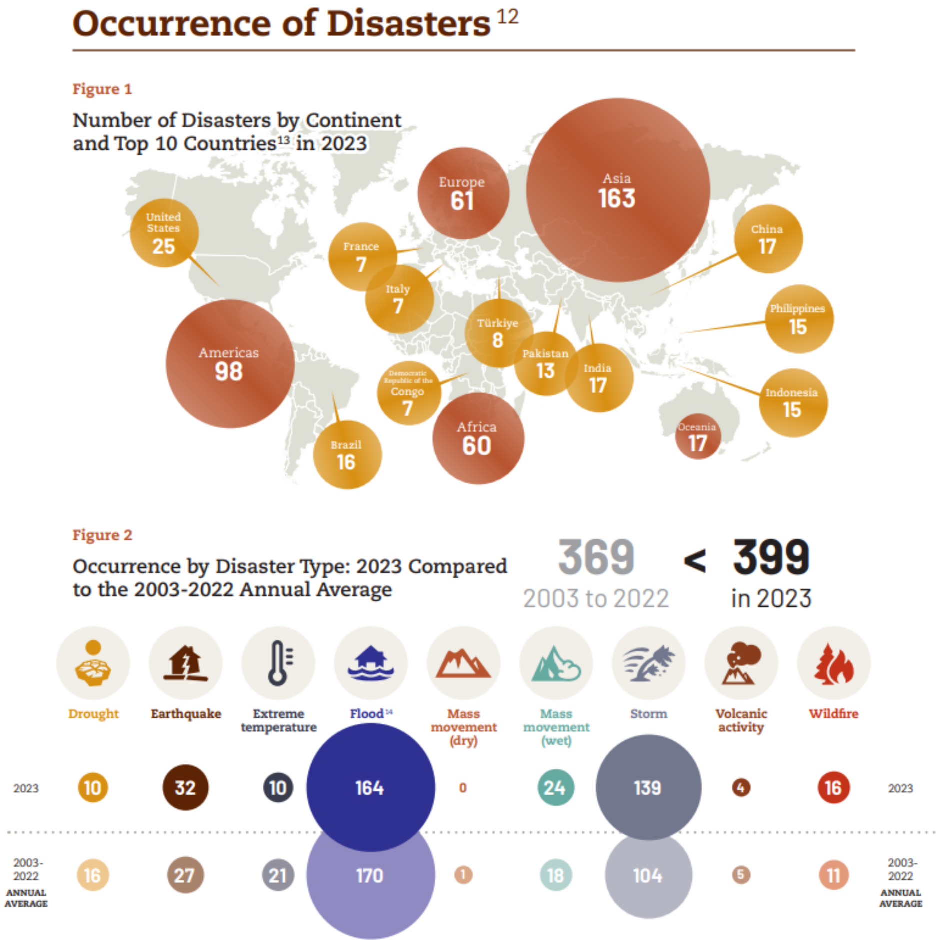

Figure 2: Number of Disasters Worldwide in 2023. Report from the Centre for Research on the Epidemiology of Disasters (CRED)

The latest Emergency Events Database (EM-DAT) global report indicates that the number of disasters recorded in 2023 exceeded the annual average between 2003 and 2022. Among these, the disaster categories that surpassed the average include earthquakes, landslides, heavy rainfall, and wildfires. However, floods and rainfall accounted for the majority of disasters. These events resulted in 86,473 fatalities and impacted 93.1 million people. Economic losses surged to an estimated USD 202.7 billion, highlighting the profound socioeconomic repercussions of these events. Of the 399 disasters recorded worldwide in 2023, 61 occurred in Europe. The most devastating event of the year was the earthquake that struck Türkiye and the Syrian Arab Republic in February, claiming 56,683 lives and causing USD 42.9 billion in damages. This seismic event alone accounted for two-thirds of the total fatalities recorded by EM-DAT that year.

EM-DAT disaster data indicates that 159 disasters were recorded in Italy between 2000 and 2025. Of these, 100 were natural disasters and 59 were technological disasters. Among the natural disasters, the database reports 1 biological disaster, 9 climatological events, 14 geophysical events, 41 hydrological disasters, 1 industrial accident, 34 meteorological events, 4 mixed disasters, and 55 transport-related disasters, totaling 54,565 fatalities. A significant proportion of the transport-related disasters stem from illegal immigration attempts, as migrants seek to enter the country, illustrating the global nature of disaster causes that can affect a nation.

1.2 Definition and Classification of Disasters

According to the terminology of the United Nations Office for Disaster Risk Reduction (UNDRR), a disaster is defined as "a serious disruption of the functioning of a community or society at any scale due to hazardous events interacting with conditions of exposure, vulnerability, and capacity, leading to one or more of the following: human, material, economic, and environmental losses and impacts." Hazard, vulnerability, exposure, and coping capacity constitute its fundamental equation:

$$R = (H \times V \times E) / C$$

This means that disaster risk is the result of the interaction between physical events in a given area and period, in relation to the social, economic, and environmental conditions that determine the vulnerability of the affected population. Hazard (H) is defined as the inherent property of a system or substance that can cause harm or damage to health, life, property, or the environment, meaning it refers to the potential to cause damage. Vulnerability (V) is the degree of susceptibility of a system or community to the damage resulting from a disaster, and exposure (E) is a factor related to the space and time in which the event may occur, referring to the number of people, properties, and systems present in at-risk areas. Coping capacity (C) refers to the ability of a community or system to withstand, absorb, adapt to, and recover from the effects of a disaster (Lavell et al., 2012; Vatsa, 2004). In other words, it indicates that an increase in the capacity to cope with or mitigate the effects of a catastrophe can reduce disaster risk, recognizing that the system is not passive but has the ability to respond and adapt.

The mathematical model suggests that even with a high level of exposure or vulnerability, a strong response capacity can significantly reduce disaster risk (Baker, 2009; Natural Disasters, 2022). Risk does not necessarily increase exponentially with the recurrence of potential events but is linked to the magnitude of the event, the degree of human social vulnerability, and the capacity to respond (Karydi, 2025).

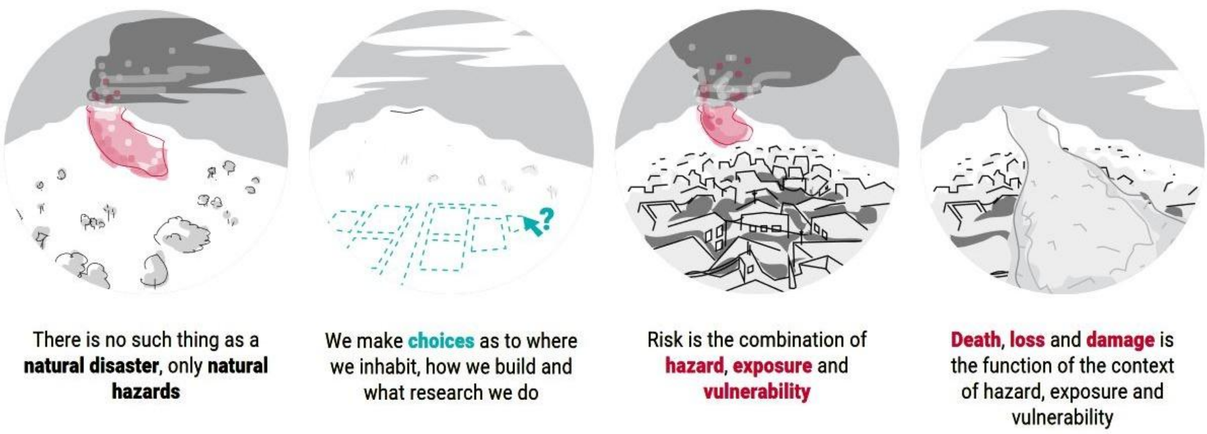

Figure 3: Risk and the context of hazard, exposure, and vulnerability. Source: UNDRR (2019).

It is important to note that the UNDRR does not recognize the term "natural disasters", but rather "natural hazards", which may lead to disasters. In this way, the office reinforces the idea that disasters are not external shocks but rather stem from the complex interaction between human development processes that create conditions of exposure and vulnerability. However, human activity can influence the magnitude of natural risk, as seen in the case of climate change. Nevertheless, disasters triggered by natural phenomena have been widely popularized as "natural disasters" worldwide, including in scientific literature.

1.2.1 Classification of Disasters

Natural events that cause deaths, injuries, and material damage can be identified using various terms such as emergencies, natural disasters, catastrophes, calamities, and cataclysms. Generally, these terms suggest an increasing scale of severity, but vocabulary, context, and interpretations of each term are not fixed in the literature, which conventionally uses "disaster" as a general designation for all these categories of events. According to Wirasinghe et al. (2013), this degrades the quality of datasets, as different databases may use varying classifications for the same event, leading to inconsistencies in identifying hazard potential, determining appropriate response measures, and allocating resources. The authors argue that disaster classification should consider not only the nature of the event but also its magnitude, frequency, affected area, and the number of victims. For this reason, they propose a multidimensional approach to classification, which takes into account both immediate and long-term impacts:

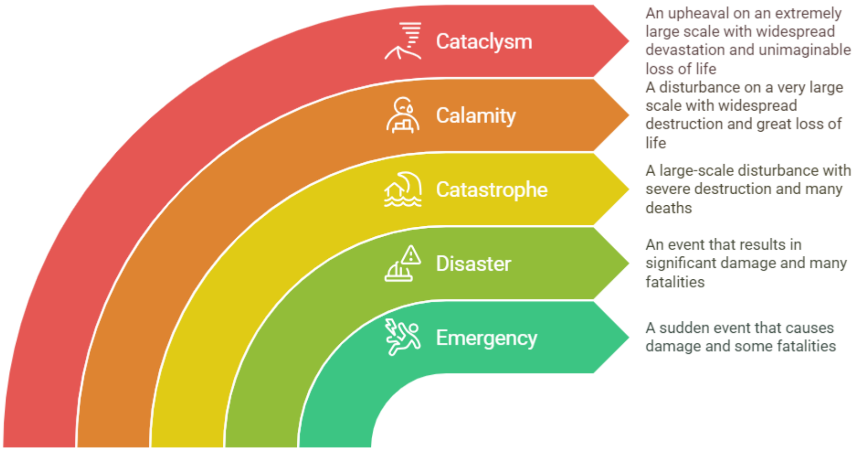

Figure 4: Classification of Events According to Their Severity. Source: Author, based on the work of Wirasinghe et al. (2013).

A significant portion of the literature and practical experience in the field of disaster risk reduction (DRR) classifies disasters as either natural or anthropogenic (Wirasinghe et al., 2013). Further subdivisions can be made, such as technological disasters (Wisner et al., 2004; Kusumastuti and Viverita, 2012). Natural disasters result from geophysical and climatic processes and include events such as earthquakes, tsunamis, volcanic eruptions, and cyclones (Rivera and Miller, 2008). Anthropogenic or environmental disasters are related to human-induced events that cause environmental damage, such as pollution, industrial accidents, and economic crises. Sociotechnical or technological disasters, on the other hand, involve events related to failures in technological systems, such as power grids, transportation networks, and communication systems (Lavell et al., 2012). However, this division is becoming increasingly blurred, as even natural-origin disasters are being exacerbated by human actions, such as deforestation, unplanned urbanization, and global warming.

But specifically, which disasters are we referring to?

After years of debates on disaster typologies and classifications, initiated by the work of Wisner et al. (2003)—which examined natural hazards, vulnerability, and disasters—the UNDRR introduced the Hazard Information Profiles (HIPs) in 2021. This initiative provided a comprehensive review of the definition and classification of 302 hazard information profiles. The report was developed with technical support from experts to establish a common set of hazard definitions, aiming to monitor and review the implementation of the Sendai Framework, which calls for a data revolution, rigorous accountability mechanisms, and renewed global partnerships.

Aligned with the UNDRR-ISC Hazard Definition and Classification Review technical report, the HIPs are categorized into eight hazard types. Each hazard type is further divided into subgroups and encompasses a variable number of specific hazards[1]:

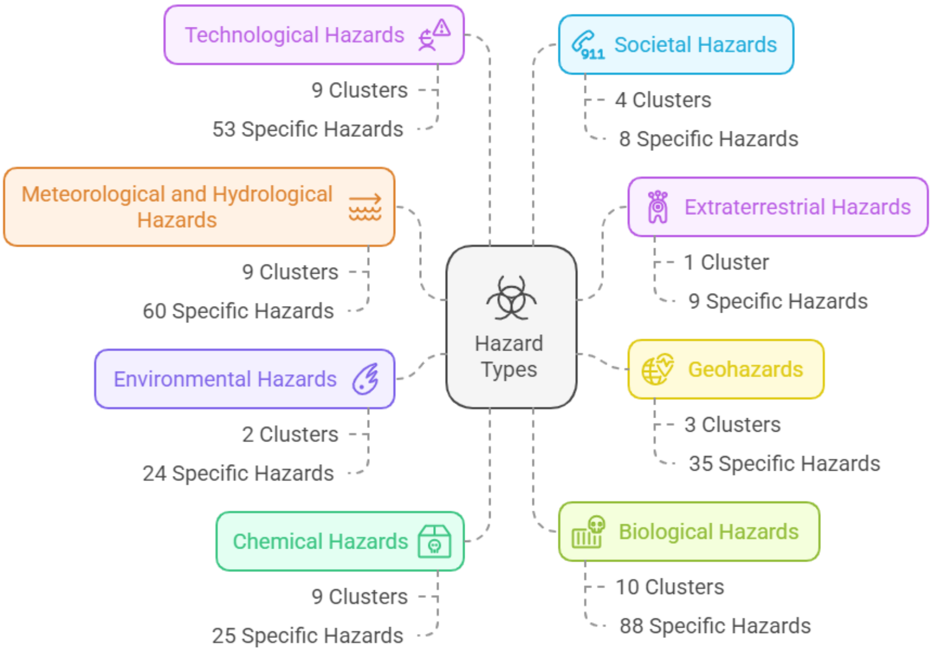

Figure 5: Types of hazards - Hazard Definition and Classification Review. Source: Author based on UNDRR (2021)

Wisner et al. (2004) argue that most disaster studies emphasize the triggering role of geotectonics, climate, or biological factors arising in nature (Bryant, 1991; Alexander, 1993; Tobin and Montz, 1997) or focus on human responses, including psychosocial and physical trauma, economic, legal, and political consequences (Dynes et al., 1987; Lindell and Perry, 1992; Oliver-Smith, 1996). Both perspectives assume that disasters represent a deviation from normality, disrupting usual social functioning, and that recovery means a return to this normal state. Wisner et al. (2004) take a different stance by placing the primary emphasis on the ways in which social systems operate to generate disasters, making people vulnerable, even though they do not deny the significance of natural factors. They stress that disasters do not occur solely due to natural events but are the product of social, political, and economic environments that create conditions of vulnerability. Some of these vulnerabilities are highly evident, such as people in adverse economic conditions being forced to inhabit high-risk areas. However, there are also less obvious political and economic factors behind disaster impacts, such as the distribution of wealth, income, and access to resources like knowledge and information among different social groups, as well as various forms of discrimination in the allocation of welfare and social protection.

Thus, the authors critique Beck's (1992) risk society, which primarily focuses on technological risks faced by highly industrialized nations and the condition of late modernity in which they exist. The

[1] Note: According to the UN General Assembly Resolution 69/284, the term 'anthropogenic' or 'human-induced' hazards in the Sendai Framework, does not include the occurrence or risk of armed conflicts and other situations of social instability or tension which are subject to international humanitarian law and national legislation (https://www.undrr.org/terminology/ hazard). As such, the report authors recognise that hazard terms related to violence and conflict included in this Technical Report are outside the scope of the Sendai Framework. In view of the calls for stronger coherence across the disaster risk reduction, development, climate change and humanitarian agendas, all of which have risk and resilience as underlying concepts, societal hazards were included as part of all-hazard considerations and ensure commonly agreed definitions for any hazard and risk. (Nota presente na introdução do relatório).

belief that disasters are universal fails to account for social, cultural, and economic vulnerabilities, which become much more visible when comparing developed and developing countries. Wisner et al. (2004) highlight that humans globally do not have equal access to resources and opportunities, nor are they equally exposed to hazards.

In most cases, a disaster is not a singular, discrete event. Vulnerable populations in less developed countries frequently experience repeated, multiple, and mutually reinforcing shocks, eroding any attempts to accumulate resources and savings. Criteria such as where people live and work, the type of buildings they inhabit, their level of risk protection, preparedness, access to information, wealth, and health status are not related to nature itself but rather are social attributes that determine their exposure to risk. In other words, vulnerability varies according to class (which influences income and living conditions), gender, ethnicity, age group, psychophysical conditions, and immigration status.

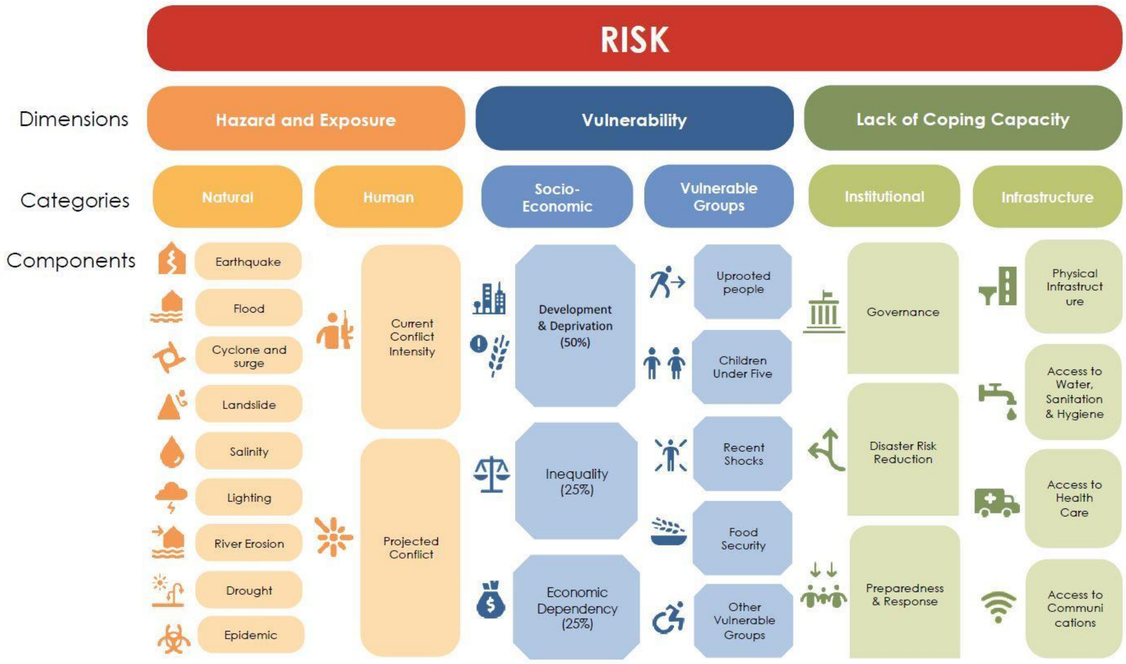

Figure 6: Dimensions, Categories, and Risk Components Retrieved from the Bangladesh INFORM Sub-National Risk Index 2022, UNDRR (2022)

Quarantelli et al. (2006) point out that disasters can reveal systemic fragilities, exposing deficiencies in social and economic infrastructures. The COVID-19 pandemic, for example, underscored the need for more robust preparedness for unexpected global emergencies. The UNDRR argues that, while disasters themselves are not inherently discriminatory, their impacts are, disproportionately affecting the poorest and most vulnerable populations by exacerbating structural inequalities. In this sense, disasters serve as indicators of development failures. Factors such as poverty and inequality, poorly planned and poorly managed urban and regional development, climate change, and environmental degradation directly influence vulnerability, exposure, and coping capacity in the face of hazards.

The mathematical formula may lead to the mistaken interpretation that disasters are always quantifiable. Beyond the inherent difficulty of measuring intangible aspects of vulnerability and coping capacity, it must also be recognized that hazards themselves are not always measurable, as many are unpredictable by nature.

1.3 The Need for the Integration of a Multi-Hazard Perspective

1.3.1 Why multi-hazard?

Although Hewitt and Burton (1971) emphasized over fifty years ago the need to shift natural hazard research from a single-risk perspective to a broader and more integrated approach, coordinated efforts toward multi-hazard frameworks only began to gain significant traction in the early 1990s. Agenda 21 for Sustainable Development (UNCED, 1992), for instance, advocated for a "comprehensive multi-hazard research approach" in land use planning and disaster risk reduction (Scolobig et al., 2017). Over the past decade in particular, there has been a notable shift from hazard-focused management toward risk-oriented strategies. The adoption of the Sendai Framework and the launch of the Global Assessment Report in 2015 marked a turning point in promoting holistic perspectives that incorporate multi-hazard dynamics. The Sendai Framework calls for "promoting investment in innovation and technology development for long-term, multi-hazard, and solution-oriented disaster risk management research." These initiatives emphasize the consequences of interacting hazards and concurrent events in time and space, underscoring that risk governance should not be limited to isolated threats (Ward et al., 2022).

Despite the progress made in recent decades, the integration of multiple hazards into disaster risk management remains limited (Poljanšek et al., 2017; Zscheischler et al., 2018). Much of the research and policymaking still addresses risk from a single-hazard and single-sector perspective, without considering the interactions between different threats. In systems thinking, "the whole is greater than the sum of its parts." When applied to DRR, this principle suggests that the interaction of different hazards can lead to a greater impact than the sum of the individual effects of each isolated hazard (Kappes et al., 2012; Terzi et al., 2019). Based on this approach, the UNDRR launched the Global Risk Assessment Framework (GRAF) in 2019, establishing a working group specifically dedicated to promoting systems thinking, in which risk is addressed from a multi-hazard and multi-sectoral perspective. The impacts of extreme natural events span multiple stressors and involve different temporal, spatial, and jurisdictional scales. Additionally, they engage a wide range of stakeholders with differing values, levels of knowledge, and practices (Adger, 2006). The interaction between natural and human-induced disasters can create complex scenarios and amplify the impacts of each event (Lavell et al., 2012). Furthermore, disasters can trigger cascading effects, where an initial event sets off a series of other catastrophic consequences. A classic example is the 2011 Fukushima nuclear accident, which was triggered by an earthquake, followed by a tsunami, demonstrating how natural and technological events can combine in a devastating manner (Ferreira et al., 2023).

1.3.2 Interactions Between Risks

According to De Angeli et al. (2022), the analysis of events involving multiple hazards presents a series of challenges at each stage (hazard assessment, vulnerability characterization, risk, or impact assessment). The relationships resulting from the spatial and temporal overlap of two or more hazards can influence both their destructive capacity and the vulnerability of the elements at risk. For this reason, the researchers developed a framework divided into five stages for multi-hazard risk assessment, focusing on their interactions, causal dependencies, and the evaluation of the impact of multiple risks:

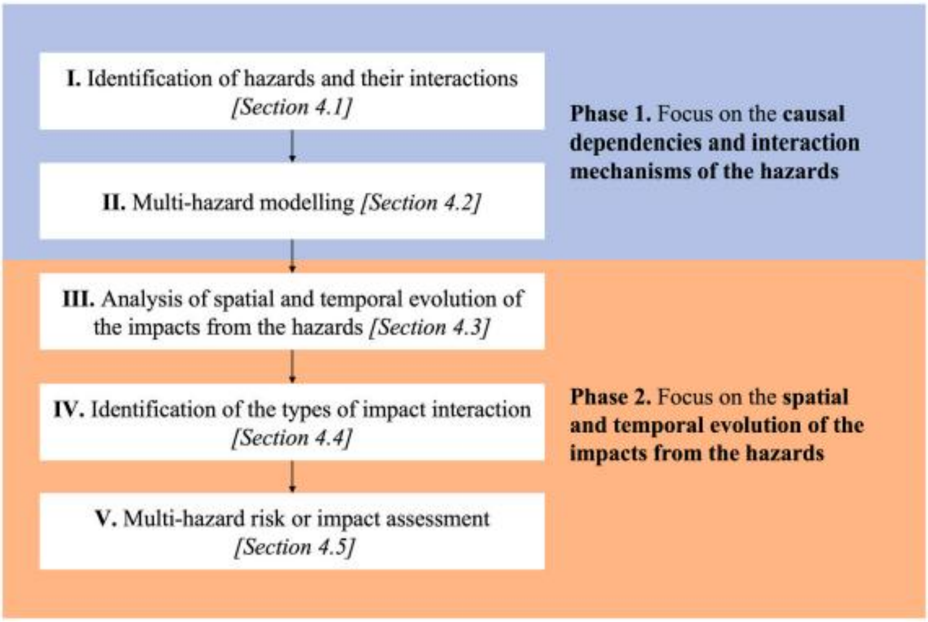

Figure 7: Framework for Multi-Hazard Risk Assessment. Source: De Angeli et al. (2022).

The authors identified six basic mechanisms of hazard interaction:

1 *Parallel hazards*: Refers to multiple hazards triggered by the same initial event. These are simultaneous (or compound) hazards that may result from large-scale processes (Tilloy et al., 2019). Examples include volcanic activity generating lava flows and ashfall, intense storms causing both floods and landslides, or tropical cyclones triggering riverine floods and coastal storm surges (Liu et al., 2016).

2 *Cascading hazards*: Characterized by sequential events in which an initial hazard triggers another. These are coupled events (Marzocchi et al., 2009). An example would be an earthquake generating a tsunami or landslides.

3 *Disposition alteration*: Occurs when a hazard alters the overall configuration of another, influencing its frequency or magnitude without directly triggering it (Kappes et al., 2010). An example is the removal of forest cover by avalanches, increasing the risk of subsequent rockfalls.

4 *Additional hazard potential*: Refers to the amplification of risks due to the spatial and temporal interaction of hazards (Tarvainen et al., 2006). For instance, an earthquake that damages flood defense infrastructure, intensifying the impact of subsequent flooding.

5 *Coincidental triggering*: Describes the simultaneous occurrence of two hazards that together trigger a third (Gill and Malamud, 2014). An example would be lightning strikes following a drought, leading to wildfires, or landslides caused by the combined effects of heavy rainfall and an earthquake.

6 *Cyclic triggering*: Refers to the mutual intensification of hazards, creating a positive feedback loop (Gill and Malamud, 2014). An example would be the lowering of riverbank slopes, which accelerates channel degradation, leading to further instability episodes.

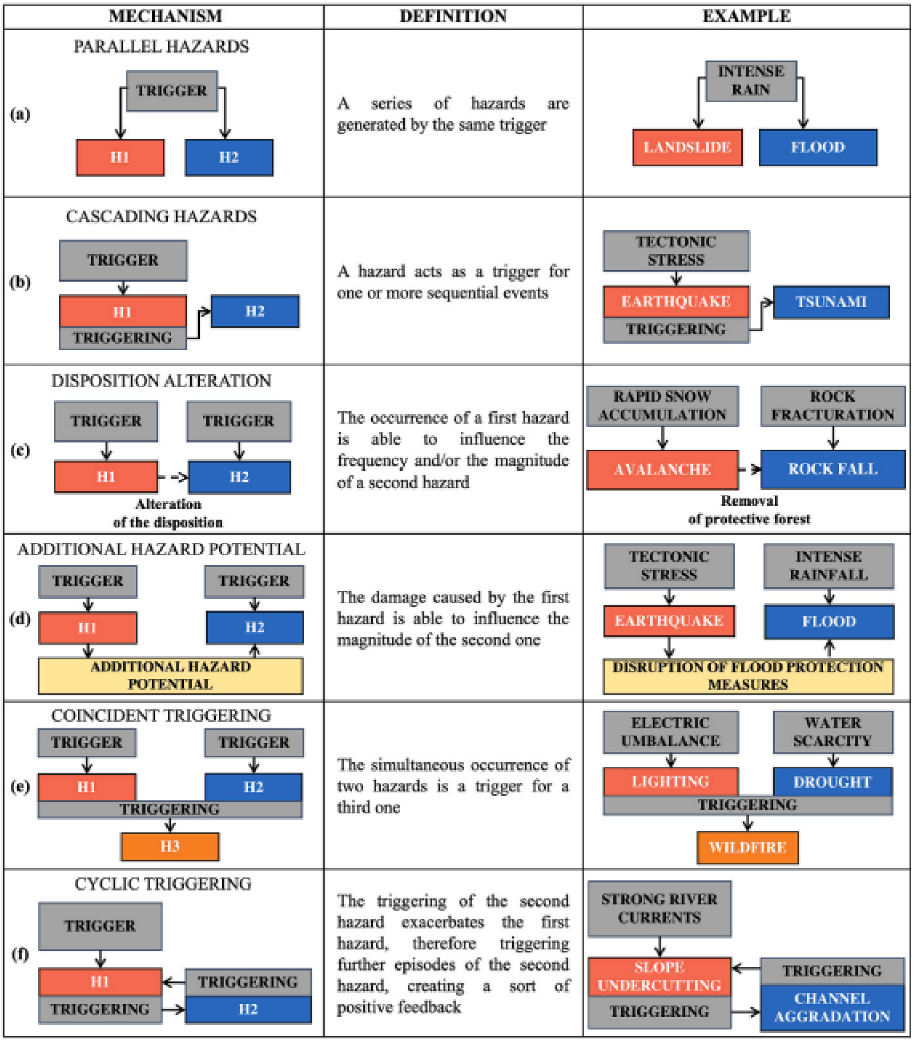

Figure 8: Types of Interactions Between Multiple Disasters. Source: De Angelis et al. (2022).

In addition to the different types of hazard interactions, it is essential to understand the interactions between the impacts caused by these hazards, which may vary across time and space. The authors divide these interactions into four categories:

1 Spatiotemporal overlapping impact
2 Temporally overlapping impact (but not spatially overlapping)
3 Spatially overlapping impact (with residual and subsequent damages)
4 Independent impacts from single hazards.

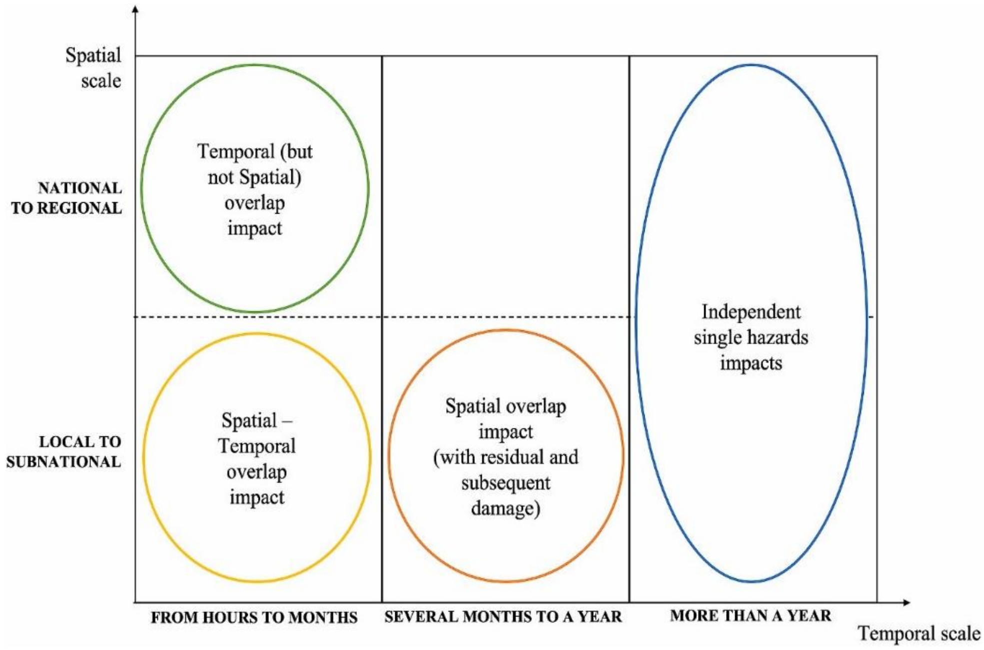

Figure 9: The Four Types of Impact Interactions. Source: De Angelis et al. (2022).

Specific hazard characteristics, such as the territorial scale and duration, can vary significantly. For instance, the onset rates of an initial event can be measured in minutes, years, or decades, potentially leading to confusing interpretations. Rapid-onset events require an immediate response (e.g., hurricanes and earthquakes) and allow for moderate timeframes to modify behaviors and practices in preparedness and mitigation phases. In this context, some resilience indicators may include evacuation plans, the level of seismic retrofitting in structures, or mandatory mitigation measures (such as storm shutters).

Slow-onset risks, such as global temperature variations, sea level rise, drought, disease, and famine, combined with less-defined spatial extents, contribute to a preference in the global change literature for conceptualizing them as "pressures." This type of disaster suggests the integration of changes in adaptive capacity, as it allows time for the modification of behaviors and practices while the event is unfolding (Cutter et al., 2008).

1.3.3 The Uncertainty Principle in the Risk Society

Desde a década de 1990, o aumento de desastres inesperados, frequentemente provocados por falhas humanas, impulsionou novas reflexões sobre a gestão de riscos. Beck (1992), ao propor o conceito de sociedade de risco, destacou a transição de um modelo baseado na quantificação e controle para um contexto marcado por incertezas não mensuráveis e incontroláveis, resultantes dos próprios processos de modernização. Segundo o autor, esse momento representaria um "marco divisório" entre um mundo em que os tomadores de decisão podiam confiar em dados e cálculos matemáticos para orientar escolhas, e um novo cenário em que os riscos extrapolam as capacidades tradicionais de previsão e mitigação. A publicação de sua obra pouco antes do desastre de Chernobyl contribuiu para sua ampla repercussão. Esse novo paradigma influenciou profundamente as teorias contemporâneas de gestão de desastres, que passaram a incorporar a complexidade e a incerteza como elementos centrais. Nesse cenário, a sociedade enfrenta um espectro ampliado de ameaças — como riscos tecnológicos, degradação ambiental, terrorismo, pandemias, poluição industrial, crises financeiras e conflitos armados — que desafiam os modelos tradicionais de controle e planejamento (Jarvis, 2007).

New multiple uncertainties arise, such as "boundaries," "voice," and "reflexivity," pointing to the need for a risk governance model that considers not only the role of the state but also the collaboration of multiple sectors and political actors (Cantelli et al., 2010). The risk society underscores the shift from a state-centered model with fixed borders to a more complex paradigm of uncertainty management, where cross-sectoral collaboration becomes essential. The concept of "boundary" highlights the need to reassess spatial and jurisdictional limitations in risk management, while "voice" and "reflexivity" emphasize risk perception and citizen inclusion in decision-making processes. Thus, the contemporary challenge is to integrate both quantifiable and non-quantifiable risks into territorial planning and management. This requires a reassessment of the role of planning, which must shift its focus from managing calculated risks to addressing uncertain and dynamic risks, facilitating the necessary transitions.

In this context, the concept of "resilience" emerges as a key element in disaster risk reduction, reflecting a significant shift in the approach to risk management. Resilience acknowledges the multiplicity of variables that influence complex systems and introduces the dimension of shared responsibilities, including active citizen engagement. Its use has intensified as uncertainties and the complexity of urban systems grow. In particular, resilience-building has become a "pillar" in disaster management, risk reduction, climate adaptation, regional economic development, and strategic planning (Davoudi et al., 2013).

1.4 Resilience

1.4.1 The Development of the Concept of Resilience

Resilience, as a concept, originates from the Latin term "*resiliere*," which means to return or recover. The term, first recorded around the year 1858, has its roots in the exact sciences (physics and mathematics) and was originally used to describe the ability of a material or system to return to its original state of equilibrium after a disturbance or to recover and reorganize in order to reestablish stability. In these sciences, a material is considered resilient when it can be flexible under stress, returning to its initial state without breaking (Bodin and Wiman 2004). In physics, resilience is not necessarily related to the magnitude of the initial displacement or the severity of the oscillations experienced, but rather to time, more precisely to the speed at which the state of equilibrium is restored (Norris et al., 2008).

It was only in the 1950s that the term was applied to psychology, encompassing human populations, and in 1973, it shifted in perspective with Holling's thesis on "ecological resilience," redefining and applying the concept to a subdiscipline of ecology (Holling, 1973). Many authors (Cutter et al., 2008) consider Holling's definition as pioneering in disaster studies, later adopted in several other fields such as epidemiology, technological evolution, and sciences related to populations or territories, urban planning, geography, and social sciences. In reality, resilience theory is part of a paradigm shift, moving from a stability- and equilibrium-based view to a world of uncertainties and threshold points (Buschbacher, 2014). In the field of disaster risk reduction studies and policies, the term was only formally recognized in the 1990s and was adopted in the field of climate change adaptation only in the first decade of the 2000s (Alexander, 2013; Plough et al., 2013; Simane et al., 2012). Thus, the concept of resilience has been applied to describe the adaptive capacities of individuals, human communities, and broader societies to both natural and human-induced disasters (Norris et al., 2008); consequently, the magnitude of impacts began to be assessed as a function of both natural and human factors (Bakkensen et al., 2017).

The formal definition of resilience by the United Nations Office for Disaster Risk Reduction refers to "the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, adapt, transform, and recover from the effects of a hazard in a timely and efficient manner," not only in the pre-disaster phase but also in the post-disaster phase (Nguyen & Akerkar, 2020). In other words, it refers both to the capacity to withstand hazardous situations with minimal damage and to effectively recover from them. In this way, the UNISDR describes resilience as a process that encompasses all phases of crisis management while reaffirming the importance of preparedness for emergency situations.

Despite this, a distinction is still made between "engineering resilience," which enables a system to return to a pre-designed state or function after a disturbance, and "ecological resilience," which allows for multiple desirable states that adapt to the environment (Gunderson, 2000). This distinction was first made by Holling himself in 1996 in an attempt to provide an interdisciplinary concept of resilience that could bridge the gap between its meaning in ecological sciences (shaped by biology) and environmental sciences (shaped by physics and engineering). The engineering definition focuses on efficiency, constancy, and predictability, aiming for a fail-safe design. It emphasizes stability close to a steady-state equilibrium, where resistance to disturbances and the speed of return to equilibrium are used as resilience metrics. Conversely, the ecological perspective focuses on persistence, change, and unpredictability from an evolutionary standpoint. It emphasizes conditions far from any stable equilibrium state, in which instabilities may lead a system to another behavioral regime, or rather, another stability domain. In this case, resilience is measured by the magnitude of the disturbance that can be absorbed before the system shifts its structure, altering the variables and processes that control its behavior (Holling, 1996; Cong Tri et al., 2017).

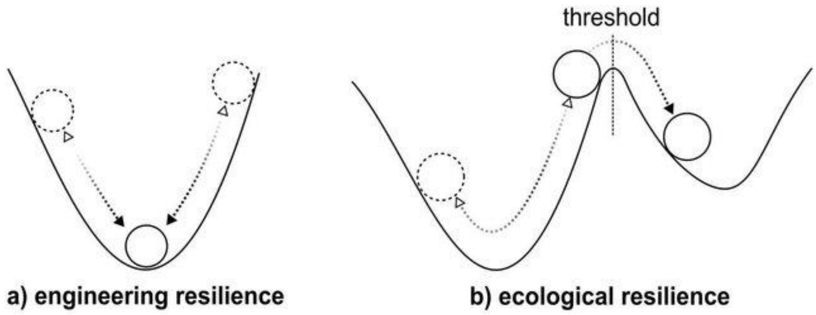

Figure 10: Comparison between engineering and ecological resilience. Source:Cong Tri et al. (2017)

Holling (1996) highlights that these two aspects of a system's stability have very different consequences for the assessment, understanding, and management of complexity and change, advocating for the use of the ecological perspective in the study of ecosystems. He also argues that the interaction between stabilizing and destabilizing forces lies at the core of development and environmental issues such as climate change, biodiversity loss, and sustainable development. Empirical experience with disturbed and managed natural ecosystems has identified key features of ecosystem structure and function that would likely not be included in the image engineers had of ecology, as well as the existence of more than one equilibrium state, contradicting the mathematical function of resilience.

The author argues that ecological change is not a linear and gradual process but rather episodic, characterized by the slow accumulation of natural capital, punctuated by sudden releases and reorganization in response to natural (internal or external) or anthropogenic events. Rare events can unpredictably alter the structure at critical moments or in more vulnerable locations. Some states are irreversible or only slowly reversible. Moreover, the spatial structure of ecosystems is heterogeneous (not uniform or scale-invariant), and scaling up cannot be represented by simple linear addition, as it is subject to nonlinear dynamics that regulate the transition between different scale ranges. "Large, slow variables not only control small, fast ones, but the latter occasionally 'revolt' and affect the former" (Holling, 1996).

The absence of a single equilibrium state in ecosystems implies that destabilizing forces play a crucial role in maintaining biodiversity, resilience, and opportunities, thereby supporting productivity and biogeochemical cycles. These systems are dynamic and capable of shifting between different functional states, with such transitions contributing to the preservation of both diversity and structure.

Similarly, management approaches that apply fixed rules to ensure constant yields tend to gradually reduce resilience, regardless of scale, making systems more vulnerable to disturbances that were previously absorbable (Holling, 1986). Given that ecosystems are moving targets, with multiple possible, uncertain, and unpredictable futures, management must be flexible, adaptive, and experimental, adjusting to the scales of the system's essential functions.

Transformative (co-evolutionary) resilience

The growing awareness of uncertainty associated with risks has prompted a shift in disaster management perspectives, moving away from prevention or control toward mitigation and vulnerability reduction (IPCC 1995, 2001, 2007; Cutter et al., 2008). This transition reflects a broader recognition of the unpredictability of natural events and the need for more flexible approaches to risk governance. Over the course of the new century, an additional transformation has emerged, driven by the integration of disaster risk reduction (DRR) policies with climate change adaptation strategies. This integration has led to both a conceptual and terminological shift toward resilience thinking (Folke et al., 2010), an approach for understanding the dynamics and development of complex socio-ecological systems (SESs) based on three interrelated components operating across multiple scales: resilience, adaptability, and transformability (IPCC 2012; O'Brien 2012).

Adaptability is understood as a component of resilience, referring to the capacity to adjust responses to changes in external drivers and internal processes, enabling development along existing trajectories within a current stability domain. The concept of adaptation emphasizes the idea that "rather than attempting to control nature, society needs to learn to live more compatibly with the natural occurrence of disasters" (White, 1974). This paradigm shift repositions the objective from eliminating risks to enhancing the capacity of SESs to respond to and adjust in the face of future uncertainty. According to Burton et al. (2002), adaptive capacity refers to a system's ability to adjust to change, moderate potential damages, and cope with disruptions. Therefore, both mitigation strategies - when applicable - and those aimed at strengthening adaptive capacity are critical to fostering resilience.

Transformability, on the other hand, refers to the ability to cross critical thresholds and establish new development trajectories. At smaller scales, transformation is grounded in multi-scalar resilience and leverages crises as windows of opportunity for innovation and renewal.

Resilience has become a ubiquitous term in disaster risk management, despite being marked by competing definitions and diverse policy implications. It remains a concept situated between the abstract and the operational (Matyas & Pelling, 2014). According to Asadzadeh et al. (2022), resilience has been conceptualized and operationalized through three distinct yet interconnected capacities: absorptive (or coping), incremental adaptive, and transformative. These dimensions offer three strategic options for decision-making in risk governance.

Absorptive capacity refers to the inherent reactive capabilities of urban systems, supporting robustness and continued functioning. However, when used in isolation, it can foster path dependencies, amplify trade-offs, and lead to unintended conflicts. Incremental adaptive capacity focuses on learning processes and adjustments in response to internal or external changes over the medium term. It blends short-term reactive capacities with gradual, forward-looking approaches to manage uncertainty. An overreliance on this form of adaptation may yield contradictory outcomes, deepen structural vulnerabilities, and produce maladaptive trajectories.

Transformative capacity denotes the deliberate and conscious ability of individuals and organizations to fundamentally reshape themselves and their societies (Ziervogel et al., 2016), leading to urban systems that evolve toward more sustainable configurations (Wolfram, 2016). According to Asadzadeh et al. (2022), transformative resilience calls for a paradigm shift in resilience theory and practice, enabling innovation and change. It entails adapting to disturbances by reconfiguring structural limitations and enabling evolution in response to both present and future shocks. Deliberate and effective choice among these strategies requires critical reflexivity, which in turn demands enhanced decision-making capacity - particularly when the perspectives of diverse stakeholders, including the most vulnerable, are considered in selecting the most appropriate approach to risk governance (Matyas & Pelling, 2014).

The authors argue that transformative resilience is at the forefront of resilience science and is expanding rapidly, although it remains a complex construct with limited contextualization and operational application. At present, the term is often addressed in sector-specific ways - focused on governance, planning, and infrastructure - or in relation to particular hazards, such as floods or droughts. Due to its context-specific nature, transformative resilience requires a precise framing (resilience *to what* and *from what*), which varies across spatial and temporal scales (Asadzadeh et al., 2022).

In urban planning, for example, it refers to the capacity of territorial systems to respond systemically and dynamically to present and future challenges through non-linear transformation processes (Brunetta et al., 2018; 2019). In sustainability contexts, it represents the ability of transitions to remain agile and produce deep, structural change (EEA, 2023). At the community governance level, it is understood as the capacity of communities to engage in collective action, address common concerns, and enhance or maintain shared well-being (EEA, 2023).

The European Environment Agency (EEA, 2023) report identifies transformative resilience as a key element in steering Europe's sustainability transitions amidst polycrises. The document highlights how sudden, complex, and interlinked crises - such as climate change, biodiversity loss, and pollution - have tested the European Green Deal and its ambition of achieving a climate-neutral, sustainable economy. These challenges risk producing short-term, reactive policy responses that may overlook systemic transformation. Responses must therefore address crisis management across political, economic, and social domains, including armed conflicts, the sluggish pace of global economic recovery and trade, and the increasing fragmentation of society along value and identity lines. The polycrisis undermines governance capacity to direct sustainable transitions while maintaining progress toward established objectives. The core question posed by the report is: "How can European policymakers ensure that the polycrisis does not result in the deceleration, diversion, or collapse of sustainability transitions?"

Among the capacities embedded in resilience theory - preventive, anticipatory, absorptive, adaptive, and transformative - only the latter two provide the capacity to move forward in sustainability transitions, rather than reverting to previous but unsustainable steady-state conditions (Asadzadeh et al., 2023; Manyena et al., 2019). This approach is especially valuable in both anticipating and responding to shocks (preventive function) and accelerating positive change by aligning short-term emergency needs with long-term goals. In this view, crises are seen not merely as threats, but as opportunities for systemic transformation (EEA, 2023).

The evolutionary perspective suggests that resilience is not a fixed attribute but rather a continuous process of change, not simply a reaction to external disturbances, but a new paradigm for spatial development. This paradigm depends on a degree of self-organization and creative agency within urban systems (Brunetta, 2016) and recognizes that systems may need to adapt to new conditions rather than returning to their original state after a disruption (Plough et al., 2013). As Manca et al. (2017) assert, "the ultimate goal of resilience is to support both social and individual well-being, with individuals - through their interactions, social ties, and power structures - acting as the primary agents of resilience."

One of the central arguments of this work is to regard the disaster event as a potential opportunity for transformation, breaking outdated paradigms and preparing communities for future challenges. For this reason, it is essential to conceptualize resilience from a transformative perspective, rejecting obsolete response models and investing in the construction of social capital.

1.4.2 The problem of the proliferation and ambiguity of the concept of resilience

In the absence of an internationally agreed definition of resilience, interpretations range from critiques of the term, concept, and metaphor to its treatment as a way of thinking, a performance, or a system's capability, or even as an end goal to be achieved. Due to this multifaceted nature, resilience has been used as a conceptual umbrella, offering as many interpretations as the different disciplinary perspectives applied to the concept, yet always employed to address complex problems through holistic interventions (Brunetta et al., 2019a). These various conceptualizations intersect across multiple fields, providing different analytical levels of resilience.

In 2013, Time magazine declared "resilience" to be a buzzword due to its conceptual imprecision and malleability. However, Norris et al. (2008) had already highlighted years earlier the proliferation of meanings associated with resilience across different fields and even within the same discipline, without a single widely accepted definition. Nearly twenty years later, the issue persists. One of the reasons for the concept's popularity is precisely its flexibility, allowing for broad and varied interpretations and definitions, making it applicable to a wide range of contexts.

Cutter and Derakhshan (2019) explicitly addressed this proliferation of meanings, pointing to concerns raised by several key authors in the disaster reduction literature: "Depending on the context, resilience infers different attributes, properties, scales, meanings, and applications of the concept (Alexander 2013). Some researchers have even questioned the basic usefulness of the idea, asking resilience for what and for whom (Klein, Nicholls, and Thomalla 2003; Manyena et al. 2011; Manyena 2014; Cutter 2018), while others use normative or empirical descriptions of resilience as a collection of attributes, assets, or capacities of individuals, communities, and places (Linkov et al. 2013; Weichselgartner and Kelman 2015). Some view resilience solely as an outcome (returning to what was), while others see it as a process and employ both qualitative and quantitative methodologies (Norris et al. 2008; Folke et al. 2010; Arado et al. 2013; Bogardi and Fekete 2018)."

They further elaborate on the same issue concerning measurement and review frameworks: "There is a variety of measurement frameworks and reviews focused on assessing disaster resilience at local to national scales (Beccari 2016; Cutter 2016; Ostadtaghizadeh et al. 2015; Sharifi 2016; Johansen, Horney, and Tien 2017; Cai et al. 2018), as well as validation and construction approaches (Burton 2015; Bakkensen et al. 2017; Jülich 2017; Cutter and Derakhshan 2018)" (Cutter and Derakhshan, 2019).

In hazard studies, resilience is generally focused on social and engineering systems and includes pre-event measures to prevent losses and damages (preparedness) and post-event strategies to manage and minimize disaster impacts. Another frequently debated issue is whether resilience should be understood as an outcome or a process. It is considered an outcome when defined as the capacity to recover or cope with a hazard, making it embedded within vulnerability. However, it is considered a process when defined in terms of continuous learning and accountability in making better decisions that enhance the ability to handle hazards through learning and adaptation (Cutter et al, 2008).

Table 1 Representative definitions of resilience

Citation first author, year	Level of analysis	Definition
Gordon, 1978	Physical	The ability to store strain energy and deflect elastically under a load without breaking or being deformed
Bodin, 2004	Physical	The speed with which a system returns to equilibrium after displacement, irrespective of how many oscillations are required
Holling, 1973	Ecological system	The persistence of relationships within a system; a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist
Waller, 2001	Ecological system	Positive adaptation in response to adversity; it is not the absence of vulnerability, not an inherent characteristic, and not static
Klein, 2003	Ecological system	The ability of a system that has undergone stress to recover and return to its original state; more precisely (i) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction and (ii) the degree to which the system is capable of self-organization (see also Carpenter et al. 2001)
Longstaff, 2005	Ecological system	The ability by an individual, group, or organization to continue its existence (or remain more or less stable) in the face of some sort of surprise….Resilience is found in systems that are highly adaptable (not locked into specific strategies) and have diverse resources
Resilience Alliance, 2006	Ecological system	The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks—and therefore the same identity. (Retrieved 10/16/2006 from http://www.resalliance.org/564.php)
Adger, 2000	Social	The ability of communities to withstand external shocks to their social infrastructure
Bruneau, 2003	Social	The ability of social units to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimize social disruption and mitigate the effects of future earthquakes
Godschalk, 2003	City	A sustainable network of physical systems and human communities, capable of managing extreme events; during disaster, both must be able to survive and function under extreme stress
Brown, 1996	Community	The ability to recover from or adjust easily to misfortune or sustained life stress
Sonn, 1998	Community	The process through which mediating structures (schools, peer groups, family) and activity settings moderate the impact of oppressive systems
Paton, 2000	Community	The capability to bounce back and to use physical and economic resources effectively to aid recovery following exposure to hazards
Ganor, 2003	Community	The ability of individuals and communities to deal with a state of continuous, long term stress; the ability to find unknown inner strengths and resources in order to cope effectively; the measure of adaptation and flexibility
Ahmed, 2004	Community	The development of material, physical, socio-political, socio-cultural, and psychological resources that promote safety of residents and buffer adversity
Kimhi, 2004	Community	Individuals' sense of the ability of their own community to deal successfully with the ongoing political violence
Coles, 2004	Community	A community's capacities, skills, and knowledge that allow it to participate fully in recovery from disasters
Pfefferbaum, 2005	Community	The ability of community members to take meaningful, deliberate, collective action to remedy the impact of a problem, including the ability to interpret the environment, intervene, and move on
Masten, 1990	Individual	The process of, capacity for, or outcome of successful adaptation despite challenging or threatening circumstances
Egeland, 1993	Individual	The capacity for successful adaptation, positive functioning, or competence…despite high-risk status, chronic stress, or following prolonged or severe trauma
Butler, 2007	Individual	Good adaptation under extenuating circumstances; a recovery trajectory that returns to baseline functioning following a challenge

Note. Because of our focus, definitions of community resilience are presented here in disproportionate frequency. Definitions describing larger (ecological) and smaller (individual) levels of analysis were representative of others in the literature

Figure 11: Relevant definitions to resilience. Source: Norris et al (2008)

Thinking about resilience involves the dynamics and development of complex socio-ecological systems (SES). It is defined by their capacity to adapt to a new equilibrium while remaining within critical limits. A socio-ecological system is configured as the integration of socio-economic processes and components (values, social and political relations, rights of use, laws, governance, economic and market relations) and biophysical elements. The way people interact with nature is embedded in their socio-economic system, and today, the anthropogenic influence on global natural processes—such as climate—indicates a growing disconnect between people and the natural environment. The core idea of resilience theory as applied to socio-ecological systems is that the inevitable uncertainties and surprises in their dynamics make it impossible to manage along predetermined trajectories. Instead of directing towards a specific goal, it is preferable to strengthen the system’s capacities and characteristics that foster flexibility for survival, learning, and adaptation throughout the dynamic process of change (Buschbacher, 2014).

Resilience, adaptability, and transformability are interrelated aspects operating across multiple scales. Adaptability is part of the resilience process and represents the capacity to adjust to changes, while transformability refers to the ability to create an entirely new system when ecological, economic, or social conditions become unsustainable (Khan et al., 2012). According to Norris et al. (2008), resilience is a process that links a set of adaptive capacities to a positive trajectory of functioning and adaptation following a disturbance. Adaptive capacities are resources with dynamic attributes. In other words, resilience is the process that connects resources (adaptive capacities) to outcomes (adaptation).

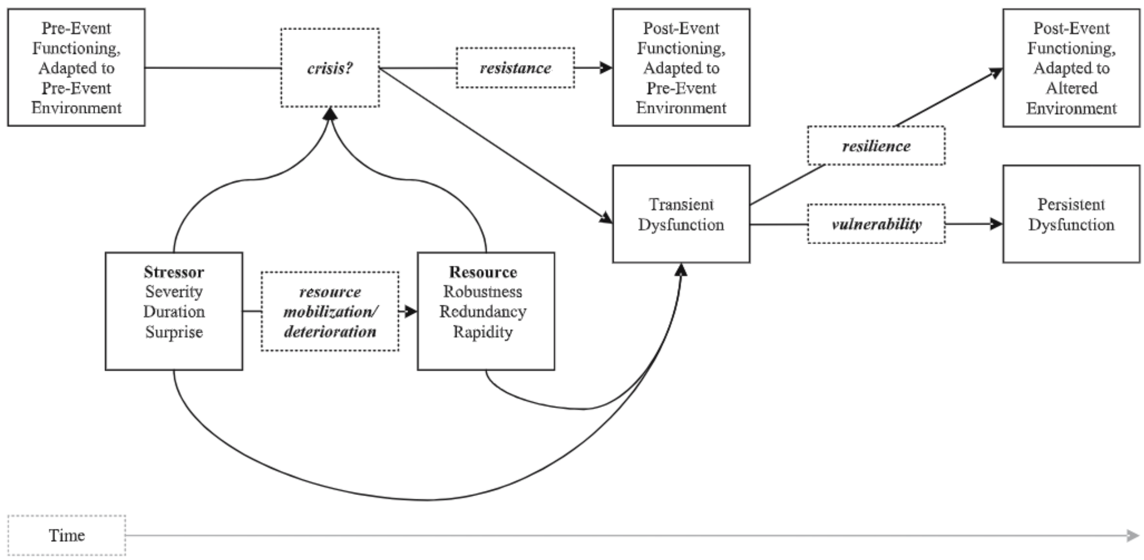

Fig. 1 Model of stress resistance and resilience over time: Resistance occurs when resources are sufficiently robust, redundant, or rapid to buffer or counteract the immediate effects of the stressor such that no dysfunction occurs. Total resistance is hypothesized to be rare in the case of severe, enduring, or highly surprising events, making transient situational dysfunction the more likely and normative result in the immediate aftermath of disasters. Resilience occurs when resources are sufficiently robust, redundant, or rapid to buffer or counteract the effects of the stressor such that a return to functioning, adapted to the altered environment, occurs. For human individuals and communities, this adaptation is manifest in wellness. Vulnerability occurs when resources were not sufficiently robust, redundant, or rapid to create resistance or resilience, resulting in persistent dysfunction. The more severe, enduring, and surprising the stressor, the stronger the resources must be to create resistance or resilience

Figure 12: Models of resistance and resilience to stress. Source: Norris et al. (2008)

There are critiques that the concept may be inadequate, imprecise, or overly "brilliant" (Bodin and Winman, 2004; Carpenter et al., 2001). For this reason, according to Norris et al. (2008), when addressed by the human and social sciences, the term should be understood as a metaphor and treated as such, without concern that its meaning must correspond to known physical properties or laws.

Munene et al. (2018) highlight that in many situations, trade-offs will be necessary between the intended outcomes of development and disaster risk reduction, even though conceptually their objectives reinforce each other. In practice, however, development has often resulted in an increase in disaster-related impacts. For example, climate change and associated hazards can be attributed to unsustainable development driven by rampant consumerism and the degradation of ecological systems. In some cases, however, disasters have provided opportunities and stimulated development, acting as a form of Schumpeterian creative destruction (Cuaresma et al., 2008).

1.4.3 Factors impacting disaster resilience

The resilience of a territory or community after a disaster is influenced by a variety of interrelated factors, including prior experience and training (Laksmita et al., 2020; Brooks et al., 2015), demographic and cultural characteristics (Cutter et al., 2008; Lowe et al., 2015; Mao and Agyapong, 2021), social capital and economic development (Lowe et al., 2015), resource management and governance (Brunetta et al., 2019b), as well as disaster preparedness and response (Polcarová and Pupíková, 2022). The interaction among these elements determines the affected communities' capacity for recovery and adaptation.

The nature and severity of a disaster directly influence the recovery capacity, but beyond that, population-related factors, such as the proportion of individuals in the working-age group, significantly impact how quickly a community can respond to emergencies. Communities that organize to monitor and react to disasters also demonstrate greater resilience, accelerating the process of reconstruction and adaptation to new circumstances.

In this regard, local governance plays a central role in managing response and recovery efforts. According to Kusumastuti and Viverita (2012), the ability and initiative of local authorities to coordinate the population are key factors in this process, and the involvement of non-governmental organizations (NGOs) can complement these efforts by providing operational and logistical support. A swift response to disasters and the rehabilitation of infrastructure are among the primary factors in reducing recovery time, particularly when facilitated by efficient administrative processes, such as expedited reconstruction permits and flexible credit payment policies in the post-disaster period (Kusumastuti & Viverita, 2012).

Raising awareness of risks and mitigation measures is an essential element in strengthening resilience. Public engagement programs and education initiatives play a crucial role in informing the population about disaster-related challenges and response strategies. Such awareness efforts also contribute to fostering a strong sense of community and mutual collaboration, preventing conflicts in the post-disaster period and promoting a smoother recovery process.

The economic sector also plays a significant role in community resilience. A diverse range of commercial activities can enhance economic resilience, allowing for a more balanced recovery across different sectors. Large businesses and industries with greater adaptive capacity tend to recover more quickly, whereas small-scale traders and fishermen, for example, often rely on government support to resume their activities. Regulations addressing debt management and providing protection for small and medium-sized enterprises (SMEs) are fundamental in stabilizing the local economy and ensuring a sustainable recovery.

Finally, active public participation in the recovery process is a determining factor. Community-led impact assessment and data collection can significantly accelerate recovery efforts and strengthen future disaster planning strategies. Thus, community involvement, combined with effective governance and well-structured support policies, contributes to building more resilient territories in the face of extreme events.

1.4.4 The operationalization of resilience

National governments around the world have developed plans and programs aimed at guiding cities, communities, and authorities to achieve resilience, with repeated calls for local administrators to be more proactive in implementing resilience plans (Handayania et al., 2019). In this sense, it is necessary to understand how to operationalize resilience beyond mere risk reduction and adaptation, but as a systemic framework that generates co-benefits through its integration with mitigation, innovation, and development (Caldarice et al., 2019). Global programs such as the Asian Cities Climate Change Resilience Network (ACCCRN) of 2008 and the 100 Resilient Cities (100RC) initiative by the Rockefeller Foundation of 2013 have developed frameworks to promote urban resilience through an inclusive process involving government, communities, and stakeholders, inviting States to be part of the proposed initiative. Urban governance is suggested as a mechanism for managing resilience, a tool capable of encompassing the legislative and practical efforts of spatial organization, environmental management, and economic activity to improve quality of life (Handayania et al., 2019). Governance includes decision-making, inclusion, and collaboration, as will be discussed in Subsection 1.11 of this work.

Locally, Caldarice et al. (2019) argued about five years ago that, despite 650 European cities being involved in various initiatives related to risk reduction, more than 90% of them lacked sufficient capacity to make long-term decisions in order to achieve significant economic, social, and ecological objectives. According to the report, few cities have developed a real capacity for adaptation and can fully implement climate change measures. Several methodological challenges remain in the theoretical domain. In this perspective, the authors suggest that the operationalization of resilience is one of the most impactful global issues for future research. This implies that urban resilience should be framed as an agent of change for future development, to rethink how cities are designed, planned, managed, and lived in the face of global challenges.

Despite the ambiguity of the concept, resilience is used at the operational level as a boundary object, meaning it is conceptually flexible enough to adapt to different community views, but it also carries a common vocabulary and ideals capable of coordinating different groups in intersecting social worlds (Normandin et al., 2019). However, this boundary object needs to be supported by a compatible intersectoral Governance model.

Handayania et al. (2019) describe a series of critical points that must be assessed on a case-by-case basis for the efficiency of Governance regarding disasters: 1) The main issue is the lack of integration between policies and levels of government, with challenges in horizontal and vertical coordination between national, regional, and local policies. Decentralization reduces the role of national governments and increases the autonomy of local governments, which may not always have the technical or financial capacity to handle disasters. 2) Territorial planning often fails to adequately incorporate disaster-prone areas and climate change as critical issues. 3) The lack of institutional capacity is also a possible limitation. The lack of qualified human resources and emergency training, low stakeholder awareness, and the inefficiency of many local disaster management agencies - especially in small cities and less developed countries - significantly reduce preparedness levels. 4) Insufficient budget and unequal distribution of resources. The authors note that the budget allocated for disaster management is often too low compared to other sectors, with most of the funds being directed toward reactive infrastructure. 5) A reactive rather than transformative approach. Most initiatives are reactive and short-term, focused solely on disaster recovery without addressing the structural causes. Strategies prioritize maintaining the status quo and rarely involve structural changes to enhance long-term resilience. 6) The lack of coordination between sectors and actors. Very similar programs with overlapping actions are implemented without communication between sectors, leading to wasted time and resources. Managing natural resources (e.g., rivers and protected areas) and inter-regional structures is a major challenge due to the involvement of multiple levels of government and different jurisdictions, making coordination complex. 7) Inequality in the implementation of resilience policies. Budget prioritization favors large cities. Even global pacts tend to choose capitals or metropolitan cities to test their ideas, leaving smaller cities to rely solely on local resources. The current approach generally does not consider the most vulnerable populations, which remain exposed to risks without adequate support.

1.5 Vulnerability

1.5.1 The Evolution of the Concept

The word vulnerability derives from the Latin word "*vulnerare*" (to be wounded) and describes sensitivity to disruption or stress. In relation to environmental risks, it represents the potential for loss in the face of extreme events, varying geographically, over time, and among different social groups

(Lei et al., 2014). According to Cutter et al. (2008), the literature divides into explaining the causal structure of vulnerability. Some approaches argue that it arises from underlying social conditions, reflecting patterns of differential access to resources and susceptibility to loss. Another perspective defines it by the potential exposure to hazardous events, considering vulnerability as a function of proximity to risk. A third approach proposes the integration of biophysical and social vulnerability, considering risk and society's response at the local level. Vulnerability results from the interaction between different factors. Risk represents the objective probability of a disaster occurring, while mitigation measures seek to reduce its impact. The geographical filter, including the conditions of the territory and its proximity to risks, directly influences the population's exposure. The social fabric, determined by the community's experience with disasters and its capacity for response, recovery, and adaptation, is a key factor in social vulnerability. The combination of these elements defines the overall vulnerability of a location, demonstrating that physical and social factors overlap in generating risks (Cutter et al., 2003).

According to the same authors, research on vulnerability follows three fundamental principles: the identification of conditions that make people and places susceptible to extreme events; the exposure model, which examines the relationship between hazards and the location of affected populations; and vulnerability as a social condition, reflecting society's resilience and its capacity to respond to risks. However, despite progress in understanding biophysical vulnerability and the built environment, there is still limited knowledge on the social aspects of vulnerability. Social vulnerability stems from socioeconomic inequalities such as age, income, race, health, and housing type, in addition to territorial factors such as urbanization and economic growth. The difficulty in quantifying social vulnerability means that these losses are rarely included in official disaster estimates (Cutter et al., 2003).

Assessing the impacts of disasters is essential for forecasting needs and guiding policies, considering both physical impacts (deaths, infrastructure destruction, agricultural and environmental losses) and social impacts (psychosocial, demographic, economic, and political). The severity of the impact depends on the speed of the event's onset, intensity, scope, and the availability of early warning signs. Losses can be direct, such as structural damage, or indirect, such as the disruption of production chains (Lindell and Prater, 2003).

Several conceptual models have been developed to explain vulnerability to hazards. The Pressure and Release Model, by Blaikie and Wisner et al. (2004), traces the progression of vulnerability from its root causes to dynamic pressures and unsafe conditions, although it does not adequately address the interaction between human and environmental systems. Turner et al.'s (2003) Vulnerability/Sustainability Framework uses a place-based approach, considering vulnerability within broad contexts that influence it, but does not clearly distinguish between exposure and sensitivity, nor does it include a temporal dimension that defines the start and end of vulnerability. Cutter's (1996); Cutter et al. (2000) Risk Place Vulnerability Model integrates system exposure and social vulnerability but does not consider the root causes of pre-existing social vulnerability, broader contexts, and post-disaster impact and recovery processes (Cutter et al., 2008).

According to Lindell and Prater (2003), reducing vulnerability to disasters should be a collective effort. The authors illustrate this issue in two distinct sectors, arguing that even if a physical structure is protected, its functionality can be compromised by the disruption of critical connections such as infrastructure and suppliers. Similarly, businesses and local governments face difficulties maintaining service delivery during recovery, as the loss of revenue may impair their response capacity. Among the social impacts, psychosocial effects impact mental health and include symptoms such as anxiety and depression. Sociodemographic effects are related to housing, with the poorest being the most affected. In the economic realm, disasters cause asset losses, declines in tax revenues, and difficulties for businesses to stay active. In the political realm, conflicts may arise between victims and authorities, mobilizing social movements and influencing elections (Lindell and Prater, 2003).

Inequality exacerbates the impacts of disasters, as poor countries suffer more casualties, and recovery is slower due to a lack of resources. The decentralization of exposure to danger may reduce risks, but low-income families and small businesses typically do not have this option.

In the social sciences community, there is a broad consensus on the main determinants of social vulnerability. These include: limitations in access to essential resources such as information, knowledge, and technology; restrictions on access to political power and representativeness; social capital, understood as the presence of support networks and social connections; cultural aspects such as beliefs and traditions; the quality and age of the housing stock; the presence of individuals with physical frailties or functional limitations; and the nature and density of infrastructure and essential services (Cutter, 2001; Tierney, Lindell, and Perry, 2001; Putnam, 2000; Blaikie et al., 1994). However, there are variations in the choice of specific variables to represent these broader dimensions.

In the specialized literature, the most recognized determinants of social vulnerability are age, gender, race, and socioeconomic status. Additionally, certain population groups are more susceptible to disasters due to the absence of social safety nets or difficulty accessing formal recovery mechanisms, such as individuals with physical or mental disabilities, immigrants not fluent in the local language, homeless people, itinerant populations, and seasonal tourists. The configuration of urban space and the quality of the built environment also play a central role in social vulnerability, directly influencing response and recovery capacity in the face of disasters. Factors such as housing type, construction materials and techniques, the presence of basic infrastructure, and the availability of essential services are determinants in assessing the impacts of adverse events on affected communities.

1.5.2 Assessment of Resilience/Vulnerability

Since the early 2000s, various conceptual models, methodologies, and assessment techniques have been developed with the aim of improving both the theoretical foundation and practical applications of vulnerability and resilience. Even with the popularization of the term “resilience” and the infinite methodologies for evaluating its levels, empirical experience continued to use maps and vulnerability indicators as an integral part of its methodologies. But if indicators for resilience exist, why does this happen? Because vulnerability is part of resilience. They are not opposing concepts, but evaluating resilience levels requires measuring the vulnerabilities present, along with the assessment of characteristics that are difficult to measure, such as population knowledge and response capacity. If resilience assumes that it faces uncertainties and changes and must be flexible and innovative, its quantitative measurement becomes impossible, allowing only comparative studies between states of the same system at different times or across distinct areas. Vulnerability, however, is more easily quantifiable, especially in its environmental aspect. Social vulnerability, in turn, has been consolidated over the years from a demographic perspective, and thus, is quantifiable. More recent experiences use mixed methodologies, starting from the quantification of vulnerability or resilience to integrate qualitative studies.

The need for conceptual precision persists, leading most academic works to carefully specify the adopted definition. Furthermore, the very nature of resilience results in fundamental differences in measurement methodologies. On one hand, empirical approaches seek to determine the current state of resilience based on observable indicators; on the other, normative approaches propose to assess what could be achieved based on external goals or standards. These conceptual and methodological divergences contribute to the lack of a standardized model for measuring resilience, making it difficult to compare across different contexts and spatial scales (Cutter and Derakhshan, 2019).

The Use and Selection of Indicators

Since the 1960s, research on social and environmental indicators has been a relevant field within the social sciences, with initial development focused on theoretical and methodological issues. At the turn of the millennium, this line of research experienced a revival, particularly in the field of sustainability, resulting in the creation of widely used indices, such as the Human Development Index (HDI) from the United Nations Development Programme (UNDP, 2000). Other institutions also followed this trend, including the World Bank (2001), the National Research Council (2000), and the U.S. Environmental Protection Agency (2002). However, until 2003, there was still no consistent set of metrics for assessing vulnerability to environmental risks, a challenge addressed by Cutter et al. (2003) in their first methodological proposal. This model was later refined by the same authors and solidified Susan Cutter as the leading reference in studies on social vulnerability. Since then, different approaches have been developed, each with specific configurations and emphasizing particular characteristics of the analyzed systems.

The success of using indicators lies in the facilitation of decision-making processes, creating a quantifiable metric that justifies the choices made or provides directions for establishing more equitable urban policies, considering the most vulnerable areas in mathematical models. The literature presents different approaches for assessing resilience to disasters, ranging from the local to the national level (Beccari, 2016; Cutter, 2016; Ostadtaghizadeh et al., 2015; Sharifi, 2016; Johansen, Horney, and Tien, 2017; Cai et al., 2018). However, the lack of a standardized model reflects the diversity of perspectives on resilience and the difficulty of consolidating a unified set of indicators (Cutter and Derakhshan, 2019). Schipper and Langston (2015), in analyzing 17 widely recognized resilience indicator sets, concluded that comparing them is extremely complex due to conceptual and methodological discrepancies. The study also pointed out that, although individual indicators may seem irrelevant in isolation, when combined with qualitative information about the context, they can provide an indication of the construction or erosion of resilience. Furthermore, the authors emphasize that resilience cannot be assessed solely by indicators of well-being and subsistence, but neither can it be measured without this information.

Even after 25 years of research, much of the recent studies on disaster risk reduction begin with the selection of different indicators, highlighting the persistence of the lack of consensus in the field. However, some common premises had already been highlighted by Cutter et al. (2008), including the need to address vulnerability from a socio-ecological perspective, the importance of local-level studies, the conceptualization of vulnerability as a matter of equity or human rights, and the use of vulnerability assessments to identify risk zones and support pre-impact planning. Conceptual and methodological challenges also include the transition from studying a single stressor (hazard) to multiple stressors (global environmental changes), incorporating scalar dynamics in vulnerability analysis, and the need to integrate population perceptions into the theoretical model, ensuring applicability in distinct local contexts (Cutter et al., 2008).

Cutter et al. (2008) highlight that indicators can be used for different purposes: to establish comparisons between distinct territorial units or to create a baseline at a specific point in time, allowing for the monitoring of changes over the years. Ideally, the same set of indicators would serve both functions. In practice, however, the assignment of different weights to the same indicator, depending on local specifics, makes direct comparison between different territories unfeasible. Even the statistical methods used can generate significantly discrepant results.

The mapping of territorial vulnerability involves three main cognitive challenges. First, vulnerability is determined by multiple factors, including both internal elements, such as the sensitivity of the territory, and external factors, such as pressures and external shocks. Second, these factors do not operate in isolation but are interconnected, making it essential to adopt a multi-risk approach. Finally, the complexity of these interactions requires a systemic and integrated perspective, capable of capturing the dynamics of vulnerability in time and space (Doost et al., 2025).

Social Vulnerability Index

The most commonly used index for quantifying social vulnerability remains the Social Vulnerability Index (SoVI) created by Cutter et al. (2003), which considers 42 independent variables, reduced to 11 components through the application of principal component analysis (PCA). PCA is a comparative metric that facilitates the examination of differences in social vulnerability between different areas. Cutter's methodology is generally modified to give relevance to the specific local dimensions of the context, but the structure of the indicators is quite exhaustive, despite emphasizing the specific case of the authors' North American study.

The 11 dimensions are composed of:

1. Personal wealth
2. Age
3. Density of the built environment
4. Single-sector economic dependence
5. Housing stock and tenancy
6. Race – African American
7. Ethnicity – Hispanic
8. Ethnicity – Native American
9. Race – Asian
10. Occupation
11. Infrastructure dependence

Given this, authors worldwide use the SoVI dimensions, adapting them to the reality of the study area and selecting the specific variables that best describe their characteristics, especially regarding the dimensions of race and ethnicity. For this reason, the authors developed and published Disaster Resilience of Place (DROP) in 2008, which proposes a place-based approach. The model has 5 main dimensions (Cutter et al., 2008):

1. Social vulnerability
2. Response capacity
3. Recovery capacity
4. Exposure to risk
5. Mitigation and preparedness

These dimensions are calculated to integrate a community resilience index. In this way, the new approach provides a conceptual framework that allows for the comparison of different communities, integrating multiple variables - social, economic, and environmental factors - to understand community resilience.

Modeling and Processing of Indicators

Data processing is performed using mathematical and statistical methods to transform indicators into resilience scores. These scores assist in decision-making and are part of various types of decision support systems.

Processing refers to the set of techniques used to transform raw data into useful information for analysis and decision-making. It involves adjusting, combining, calculating, and interpreting the indicators. It can take various forms depending on the methodological approach and the type of data used. The most commonly used methods are described below:

- Normalization and Standardization
    - Min-max scaling
    - Z-score
    - Logarithmic scaling
- Weighting of indicators:

  - Equal weighting
  - Analytic Hierarchy Process (AHP)
  - Information Entropy
  - Principal Component Analysis (PCA)
- Construction of composite indices
  - Simple arithmetic mean
  - Weighted mean
  - Geometric mean
- Classification and typification of areas
  - Quartis or Quintis
  - K-Means Clustering
  - Hierarchical Cluster Analysis
  - Decision Trees
- Sensitivity and uncertainty analysis
  - Monte Carlo Simulation
  - Fuzzy Analysis
  - Boostraping

Table 1: Types of indicator processing. Source: Author

Processing Type	Common Methods	Application
Normalization	Min-Max Scaling, Z-score, Log Scaling	Comparison of indicators with different scales
Weighting	AHP, Entropy, PCA	Defining the relative importance of indicators
Composite Indices	Arithmetic Mean, Geometric Mean, Weighted Mean	Construction of synthetic resilience indicators
Statistical Modeling	Regression, PCA, SEM, Time Series	Prediction and analysis of determining factors
Classification	Quartiles, K-means, Decision Trees	Categorization of vulnerable areas
Sensitivity & Uncertainty Analysis	Monte Carlo, Bootstrapping, Fuzzy Logic	Evaluation of result reliability
Machine Learning	Neural Networks, Random Forest, Clustering	Advanced analytics and prediction

Modeling refers to the process of creating, developing, and analyzing models to represent systems, phenomena, or concepts from the real world. The modeling of resilience indicators can be done using different methods, depending on the objective of the analysis, the availability of data, and the theoretical approach adopted.

- Statistical modeling: allows for the quantification of resilience and its relationship with different variables:
  - Linear and logistic regression
  - Principal component analysis (PCA)
  - Factor Analysis (FA)
  - Time series model (ARIMA, VAR, GARCH)
- Modeling based on composite indices:
  - Simple index

    - Weighted index
    - Standardized scale
- Multi-criteria modeling (MCDM):
    - Analytic Hierarchy Process (AHP)
    - Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
    - Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)
    - Standardized scale
- Simulation-based modeling:
    - Agent-based modeling (ABM)
    - Modeling dynamic systems
    - Monte Carlo Simulation
- Qualitative and Participatory Modeling:
    - Delphi Method
    - Worshops and interviews
    - Participatory Evaluation
- Modeling by Machine Learning and Artificial Intelligence:
    - Artificial Neural Networks (ANNs)
    - Randon Forest & Decision Trees
    - K-means Clustering

Table 2: Types of indicator modeling. Source: Author

Modeling Type	Common Methods	Application
Statistical	Regression, PCA, Time Series Analysis	Quantitative analysis and forecasting
Composite Indices	Weighted average, normalization	Construction of synthetic resilience indicators
Multi-Criteria (MCDM)	AHP, TOPSIS, PROMETHEE	Comparison of resilience alternatives
Network-Based	Social Network Analysis, Graph Theory	Critical infrastructure and social connectivity
Simulation-Based	ABM, Monte Carlo, System Dynamics	Scenario testing and planning
Qualitative & Participatory	Delphi, Interviews, Workshops	Community engagement and social perception
Machine Learning	Neural Networks, Random Forest, Clustering	Predictive analysis and Big Data

The use of indicators faces methodological challenges, especially because they are predominantly quantitative and rely on predictable events. However, we live in a society marked by uncertainties, making it questionable whether it is possible to define if a territory is resilient to unknown risks. Insecurities are not quantifiable, and the human factor directly affects the perception, response, and consequently, the resilience of a system. Furthermore, in the case of technological disasters, the human factor can be the very cause of the event (Schipper and Langston, 2015). Most of these indices have not been empirically tested, and there is still no consensus on the best way to divide the indicators into specific dimensional scales. Most assessments are designed for predefined territorial scales—municipal, regional, or national—without a model that encompasses the interconnection between scales (Cutter et al., 2008). The scale also affects the comparability of resilience indicator results, as well as the distribution of different weights. For this reason, in recent years, we have seen an evolution of assessment indices to include qualitative characteristics.

Qualitative assessment of resilience/vulnerability

Qualitative methods use descriptions, perceptions, and subjective data for assessment. They are useful for capturing contextual, social, and political aspects that cannot always be quantified. Similarly, only a qualitative model is capable of encompassing uncertainty and the concerns of the community, which are not always measurable quantitatively or may even contradict the results of a mathematical equation.

The main qualitative methods for assessing resilience/vulnerability are:

- Delphi Method
- Interviews and Focus Groups
- Participatory risk mapping
- Discourse analysis and Text Mining

In the field of urban planning, the integration of a spatial perspective into the measurement of resilience/vulnerability led to the use of visual modeling techniques. Initially, Spatial Decision Support Systems (SDSS) were created, combining mathematical models and map creation. Nowadays, georeferencing technologies have significantly contributed to the field of DRR in urban areas. Already widely used for land-use planning, GIS systems have the ability to combine automated processing and spatial modeling, facilitating data development and visualization.

Gis-based approach to identify the spatial variability of social vulnerability.

An example of the integration of quantitative indicators with GIS modeling is the work of Frigerio et al. (2016). The study proposes a multidisciplinary methodological framework to integrate social vulnerability with seismic risk analysis in Italy. They argue that the severity of natural disasters depends not only on the magnitude of the event but also on the social vulnerability of the affected population. The main goal is to map social vulnerability and its exposure to seismic risk, using an approach based on socioeconomic indicators and GIS tools. To this end, the authors use a methodology involving four stages, combining statistical analysis and GIS.

The first stage is the selection and construction of social vulnerability indicators. After a literature review, the selection of indicators was conditioned by data availability, using the 2001 Population Census (ISTAT) and spatial databases to define the key indicators. The chosen indicators were age, employment, education, urbanization, housing quality, and ethnicity.

To reduce the number of variables and identify the latent factors that explain social vulnerability, factor analysis (FA) with Varimax rotation was used. Through factor normalization (z-score), the social vulnerability index (SVI) was constructed by combining the factors extracted from the statistical analysis and classified into four categories: high, medium, low, and very low vulnerability. The results were mapped using Q-GIS. The final stage of the study combined the SVI with the seismic risk map developed by the National Institute of Geophysics and Volcanology (INGV).

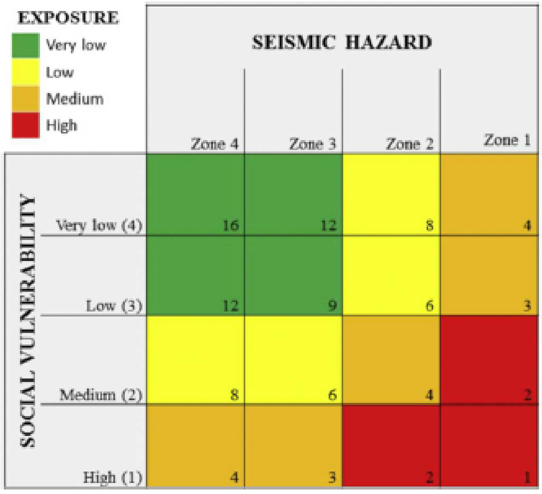

Figure 13: Risk Matrix. Source: Frigerio et al. (2016).

The results show that the country has significant heterogeneity in terms of social vulnerability. The southern regions exhibit higher vulnerability, as well as mountainous and rural areas due to the aging population. Regions more prone to earthquakes also have high levels of social vulnerability. Additionally, the most densely populated cities are more vulnerable due to urban and economic factors. The exposure map identifies regions such as the central and southern Apennines, as well as the Sicily region, as "hotspots" of risk, where the social fabric amplifies the potential impacts of earthquakes. Furthermore, the study highlights the importance of integrating social vulnerability analysis into risk mitigation policies and land-use planning. The use of the SVI allows for the identification of priority areas for interventions, providing practical tools for public managers to plan response and recovery strategies.

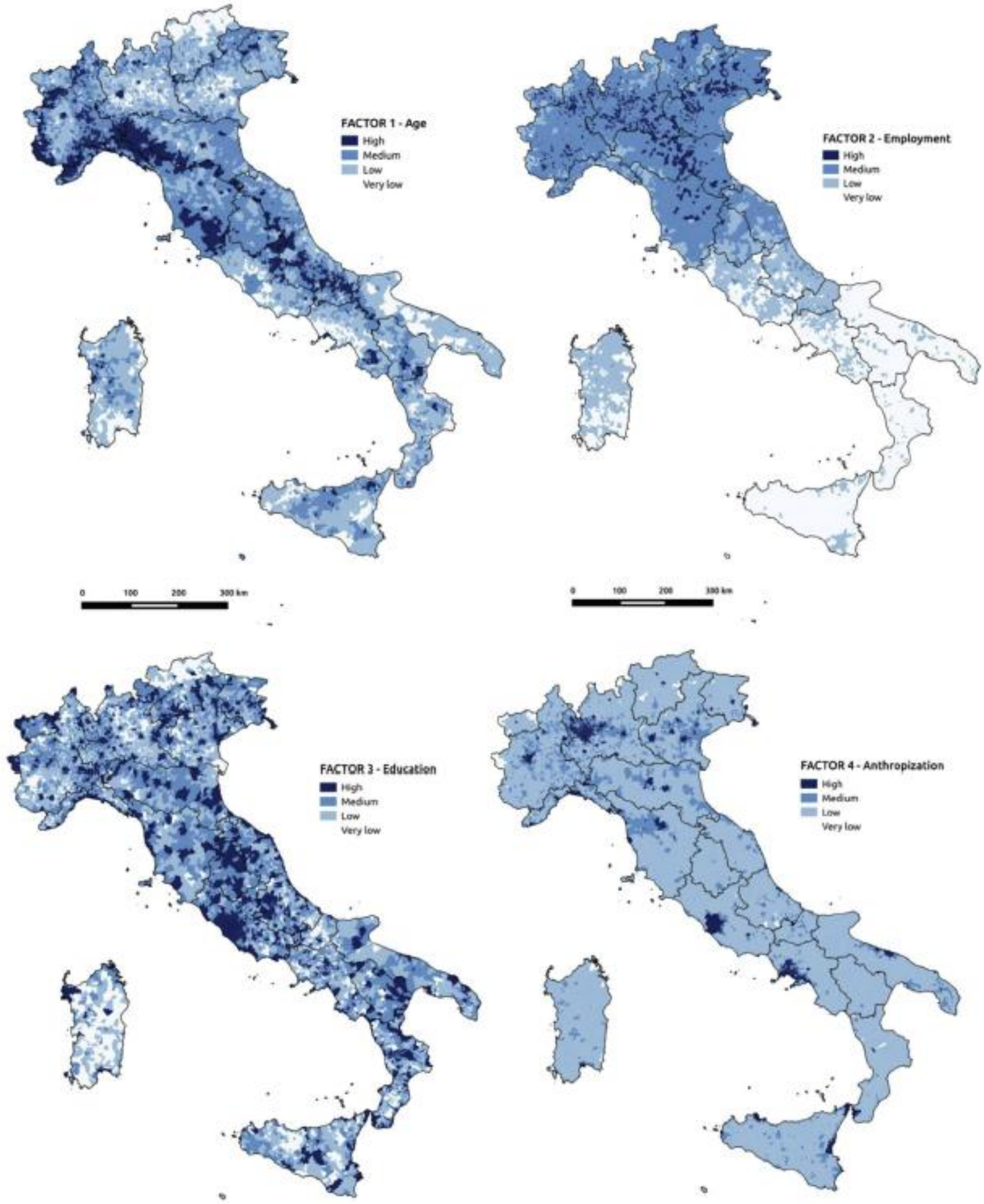

Figure 14: Spatial distribution of the four factors derived from factor analysis: age, employment, education and anthropization. Source: Frigerio et al. (2016).

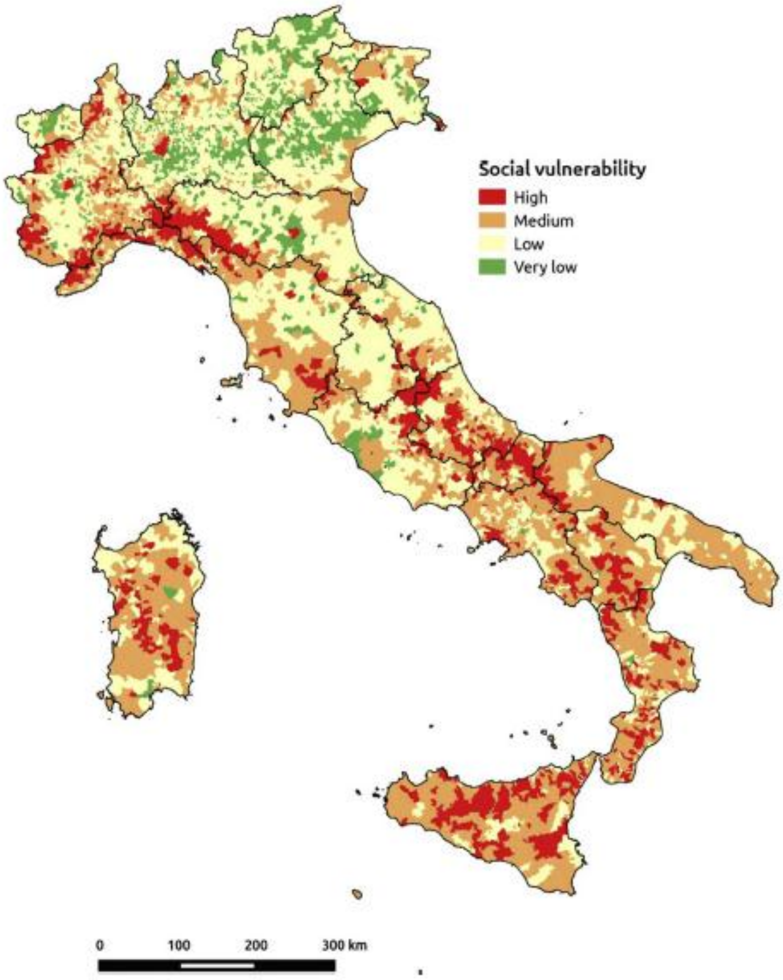

Figure 15: Social vulnerability index map. Source: Frigerio et al. (2016).

The R3C-GeoResilience

A more recent study from the University of Torino led to the development of a plugin called R3C-GeoResilience, which, through place-based mapping of territorial vulnerabilities, aims to strengthen institutional learning capacity and support the decision-making process. The plugin is open-source and designed in the QGIS environment, taking into account various components of sensitivity (environment, infrastructure, economy, society, and cultural heritage). R3C offers a detailed spatial analysis, identifying areas vulnerable to various points and/or dynamic disturbances (Doost et al., 2025).

The tool uses a correlation matrix that identifies the relationships between sensitivity and pressures/shocks, assigning a specific weight to each indicator that reflects the actual incidence of each phenomenon on the territorial system, using a Likert scale. Subsequently, the values are normalized and inserted into the matrix, where they will be used as weights for the indicators in order to calculate the overall vulnerability of the territory.

Sensitivities			Pressures		Shocks			
			P1	P2	S1	S2	S3	S4
			SC - Soil Consumption	DE - Depopulation	FL - Floods	SR - Surface run-off	LS - Land slides	UHI - Urban Heat Island
A. ENVIRONMENT AND LANDSCAPE	A1	IMP - Impermeability	1	0	1	1	1	0,67
	A2	TR - Availability of planted trees	1	0,67	1	1	0,33	1
	A3	GR - Availability of Green spaces	1	0,67	1	1	0,33	1
B. BUILDING, HERITAGE, INFRASTRUCTURE	B1	RIA - Road infrastructure availability	0,67	0,67	0,67	0,67	0,67	0,33
	B2	CHS - Cultural heritage sites	0,33	0,33	1	1	0,33	0,67
	B3	BA - building abandonment	0,33	1	0,33	0,33	0	0,33
	B4	CLA - Cycling lanes availability	0,33	0,67	0,33	0,33	0,33	1
	B5	ESA - educational services availability	0	1	0,33	0,33	0,33	0,33
C. ECONOMY AND POPULATION	C1	PD - Population density	1	1	1	1	1	0,67
	C2	EC - Elderly component	0	0,67	1	1	1	1
	C3	IC - Immigrant component	0	0,33	0,67	0,67	0,67	0,67
	C4	SAS - Social assistance servises	0	1	1	1	1	0,67

Figure 16: The correlation matrix between sensitivity, pressures, and shocks, based on the R3C methodology. Source: Doost et al. (2025).

The authors highlight that resilience is a place-based concept, meaning that its measurement requires flexibility in the selection and application of spatial indicators. In this context, the R3C GeoResilience plugin stands out for its adaptability, allowing for the definition of new custom indicators for each component based on the characteristics of the territory, as well as the continuous updating of monitored variables. The indicators can be adjusted according to various factors, such as the availability of new data, scientific advances, and the incorporation of variables that were not previously considered.

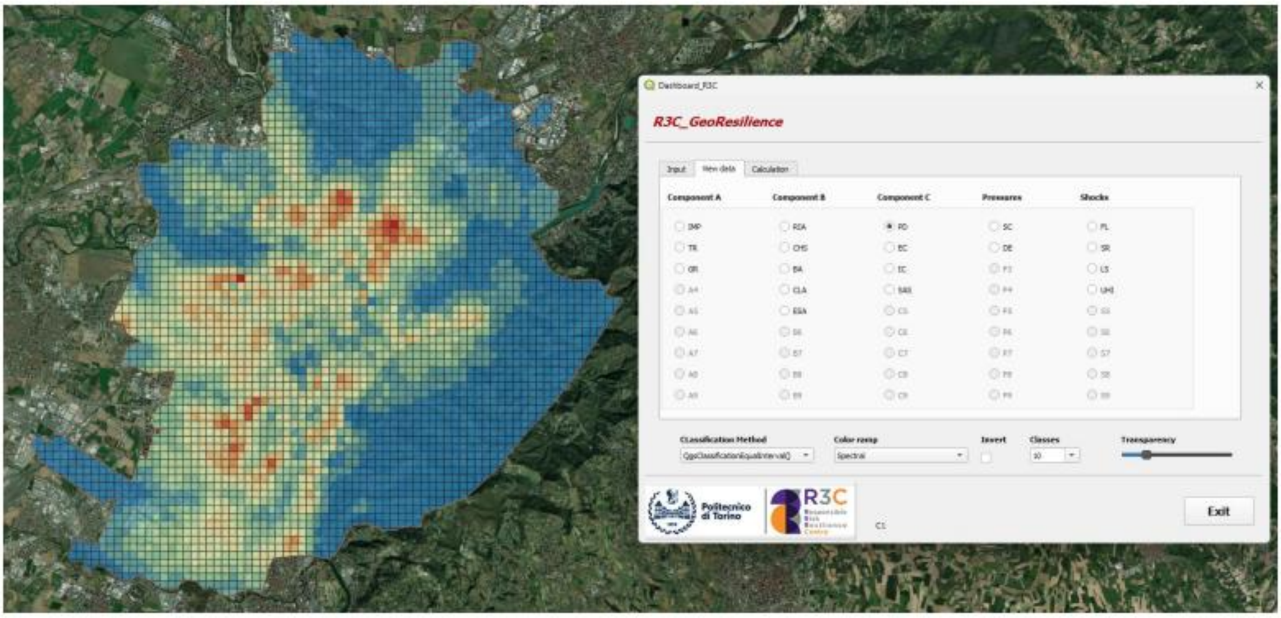

Figure 17: Overview of the interface showing individual sensitivity, pressure, and shock indicators. Source: Doost et al. (2025).

The plugin is aimed at public administration, requiring a higher level of digital skills for its use. However, the GIS interface is undoubtedly simpler and more user-friendly compared to the usual tables and graphs derived from mathematical models. It also offers the ability to customize and interact with the weights.

1.6 Why resilience and not vulnerability?

In the first decade of this century, there was a notable shift in the rhetoric surrounding hazards, moving from vulnerability to resilience, a more proactive and positive view of community involvement in risk reduction (Cutter et al., 2008). Vulnerability and resilience are often treated as opposing concepts, although this association is not entirely accurate. Both are dynamic processes, but a static approach is often chosen to facilitate their measurement. As noted by Cutter et al. (2008), vulnerability refers to the pre-event, inherent, or qualitative characteristics of social systems that increase the potential for harm. Essentially, vulnerability is a function of exposure, which determines who or what is at risk, and the sensitivity of the system, which measures the degree to which it can be negatively impacted. This perspective reflects a reactive action, where a territory or community can only assess its level of resilience after a disastrous event. While it is possible to measure vulnerability levels and track improvements, this approach requires an exact definition of risk and a prediction of its likelihood. In times of uncertainty, the need for proactive action becomes evident, preparing the community and territory for a broader range of risk possibilities, including those that are unknown. For this reason, the discourse on vulnerability gave way to resilience.

From the 2010s onwards, the concept of urban resilience became increasingly relevant as a central approach in urban development. This trend reflects the growing need to integrate adaptation and mitigation principles in the face of complex and unpredictable challenges, as highlighted by Karydi (2025). In this context, vulnerability assessment was complemented or replaced by plans focused on strengthening the response and recovery capacities of social systems, as well as improving the inherent conditions that allow the absorption of impacts. Furthermore, these plans aim to promote post-event adaptive processes that facilitate reorganization, change, and learning in the face of threats. Thus, while vulnerability highlights the elements that contribute to probable risk, resilience focuses on the strategies and mechanisms that support overcoming and adapting to a diversity of possible risks.

1.7 Resilience policies

In 1989, the newly established United Nations International Strategy for Disaster Reduction (UNISDR) designated the last decade of the 20th century as the International Decade for Natural Disaster Reduction (IDNDR), through Resolution 44/236. According to Rodrigues (2009), this document signaled an optimistic attitude and the conviction that the available technical and scientific resources would be effective in reducing risks. A few years later, the United Nations Conference on Environment and Development, held in Rio de Janeiro, adopted the Rio Declaration, an agreement aimed at developing strategies capable of ensuring environmental protection and social solidarity. In particular, the Agenda 21 (UN, 1992) dedicates one of its 40 chapters to the role of the scientific and technological community (Chapter 31) and another to the importance of information in decision-making processes (Chapter 40) as fundamental aspects in supporting the principles of sustainable development in practice (Di Cesare, 2018). The establishment of administrative-academic networks redirected public policies, grounding decision-making in science.

In 1994, the First World Conference on Natural Disaster Prevention was held, presenting the Yokohama Strategy and Plan of Action, which outlined policies for disaster risk reduction with a focus on community-based social guidelines. The human dimensions of risk reduction began to attract international attention (Cutter et al., 2008). Following its conclusion, the United Nations established a permanent secretariat in Geneva to promote the international strategy. In 2002, the Johannesburg Plan of Implementation identified the need for integrated action on multiple hazards, prioritizing the fight against vulnerabilities, risk assessment, and disaster management. The expanded framework of threats represented the first step toward linking global public agendas, to the extent that, in 2007, the Fourth Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) recognized the importance of reducing not only the physical vulnerabilities of the environment but also social vulnerabilities. That same year, the United Nations Framework Convention on Climate Change emphasized the connection between climate change adaptation and disaster risk reduction.

In the same year, an important national-level strategy emerged in the United States. The notion of disaster-resilient communities gained government support when FEMA announced its National Mitigation Strategy, an effort to reduce losses through public-private partnerships (Cutter et al., 2008). The Impact Project, which formalized the initiative in 1997, established specific criteria for communities to be considered resilient. To achieve this status, communities had to: (1) build partnerships with all relevant stakeholders, (2) identify their hazards and vulnerabilities, (3) implement hazard risk reduction actions, and (4) communicate their successes to others (National Research Council, 2006). This initiative underscored the role of communities in disaster identification and preparedness. However, with the 2000 presidential election, the initiative was discontinued without any evaluation of its effectiveness.

The 2000 Millennium Declaration and the Millennium Development Goals selected 18 specific indicators for poverty reduction. Authors such as Cutter et al. (2008) suggest that these indicators raised awareness of the intrinsic link between poverty reduction and natural disasters. In 2005, the World Conference on Disaster Reduction in Kobe represented the culmination of a long process of reflection that led to the Hyogo Framework for Action 2005–2015, an international agreement among 168 member states that established guidelines for disaster risk reduction at a global level. The conference emphasized the concept of resilience as an essential response to addressing urban vulnerabilities, proposing strategies to enhance the recovery capacity of territories exposed to multiple risks. It identified the need and the means to build resilient communities by integrating prevention, mitigation, preparedness, and vulnerability reduction into sustainable development policies. Thus, member states reaffirmed their responsibility to protect populations and to take part in the international strategic plan to create a culture of prevention based on reducing vulnerabilities (Rodrigues, 2009). The primary objective was to strengthen the capacity of local institutions and mechanisms to foster resilience and to integrate risk reduction into the design and implementation of preparedness, response, recovery, and reconstruction programs.

The development of urban agendas intensified after 2010 in light of preparations for the adoption of the Sustainable Development Goals (SDGs), the New Urban Agenda, the Sendai Framework for Disaster Risk Reduction, and, at the European level, the European Urban Agenda (2023) (Karydi, 2025). Resilience-building was highlighted both as an ultimate goal, as seen in SDG 11 and SDG 1.5, and as a mechanism for promoting institutional change, growth, and equity, as exemplified by the UNDRR's *Making Cities Resilient 2030* campaign and UN-Habitat's *Cities Investment Facility*. The 2016 Paris Agreement acknowledged the risks and impacts of climate change and the importance of engaging all levels of government and diverse stakeholders, emphasizing the intrinsic relationship between climate change actions, responses, and impacts, and equitable access to sustainable development and poverty eradication (UNFCCC, 2015 apud Karydi, 2025).

The update of the Hyogo Framework led to the Sendai Framework for Disaster Risk Reduction 2015–2030, which reinforced the importance of disaster risk reduction strategies and expanded their scope. The new framework underscores the need to integrate Disaster Risk Reduction (DRR) into sustainable development, recognizing the connection between disasters, climate change, and social and economic vulnerabilities. In this way, it seeks to align more closely with global agendas, such as the Sustainable Development Goals (SDGs) and the Paris Agreement on climate change. The Sendai Framework broadened the focus of risk reduction to encompass all aspects of society, considering both natural and human-induced hazards and addressing their impacts on cultural assets and ecosystems. To achieve this, the framework promotes the active participation of all sectors of society and establishes four priorities: (1) Understanding disaster risk, (2) Strengthening disaster risk governance, (3) Investing in disaster risk reduction, and (4) Enhancing disaster preparedness for effective response. These four priorities are intrinsically linked to urban planning, as its technical capacities for developing future scenarios can integrate user perspectives in the creation of projects and regulations. Additionally, the framework shifts away from the previous structure's emphasis on post-disaster response and recovery, advocating instead for a proactive approach centered on prevention and preparedness for interconnected risks within a multi-sectoral and multi-hazard perspective. It also highlights the need for a data revolution, promoting the collection and sharing of high-quality information to monitor risks and assess progress in disaster reduction.

In recent decades, disaster management policies have undergone a transformation, shifting from a risk-mitigation-centered approach to a more holistic vision of resilience that integrates social and development dimensions (Karydi, 2025). This advancement reflects the understanding that the resources of multilateral institutions alone are insufficient to address all impacts, making collaboration across different sectors essential. In this context, inadequately planned urban systems may become vulnerable, and the exclusive adoption of conventional risk management strategies can lead to a limited understanding of the complex interactions between human and ecological systems. The COVID-19 pandemic reinforced the importance of resilience in international policies, driving initiatives such as the European Recovery and Resilience Plans, which established one of the largest long-term budgets in the history of the European Union.

1.7.1 The lack of integration between climate policies, disaster management, and sustainable development

Scientific evidence on Earth's climate changes indicates a range of adverse impacts on multiple natural and social systems. Among the most significant consequences are the forced migration of species, habitat and biodiversity loss, damage to ecosystems, and the degradation of ecosystem services that sustain both the environment and human activities. Climate change also threatens infrastructures, agricultural and commercial systems, and drives the displacement of human populations, contributing to the growing number of climate refugees. These effects are associated with substantial economic losses, highlighting the need for proactive and effective actions for mitigation and adaptation (IPCC, 2014, 2019).

The need for rapid and structured responses to this crisis was emphasized by the Stern Review of 2006, which argued that the benefits of immediate and robust action would far outweigh the costs of inaction. The report estimated that the lack of effective measures against climate change could result in a loss equivalent to 5% of global GDP annually, indefinitely (Stern, 2006). This perspective reinforces the need for a transformational and systemic transition, capable of guiding society toward a more resilient future in the face of climate challenges.

Despite the growing concern for resilience, governance and policy formulation related to climate still face significant structural challenges. According to Thomala et al. (2006), there are four research and policy communities that operate relatively independently: disaster risk reduction, climate change adaptation, environmental management, and poverty reduction. These four areas share cross-cutting themes and face common challenges, as their causes and consequences are strongly interconnected. However, until 2006, they had not yet achieved their goals of reducing vulnerabilities, primarily because they worked in isolation (Thomala et al., 2006). The authors argue that a more collaborative and integrated approach between these communities is essential to strengthen resilience and promote effective solutions to the global climate crisis.

The convergence of these research and policy fields can enable more robust climate governance, allowing adaptation and mitigation strategies to be developed in a more coordinated manner. In this way, actions against climate change can be more efficient, avoiding redundancies and maximizing positive impacts in terms of environmental, social, and economic resilience.

Climate change adaptation	Disaster risk reduction
Approach	
• risk management • strong scientific basis • environmental science perspective • highly interdisciplinary • vulnerability perspective • long-term perspective • global scale • top-down	• risk management • engineering and natural science basis • traditional focus on event and exposure and on technological solutions • shift from response and recovery to awareness and preparedness • short term but increasingly longer term • local scale • community-based
Organisations and institutions	
• United Nations Framework Convention on Climate Change (UNFCCC) • Intergovernmental Panel on Climate Change (IPCC) • Academic research • National environment and energy authorities	• United Nations (UN) • ProVention Consortium (World Bank) • International Federation of Red Cross and Red Crescent Societies (IFRC) • International, national and local civil society organisations • National civil defence authorities
International conferences	
• Conference of the Parties (COP)	• World Conference on Disaster Reduction
Assessment	
• IPCC Assessment Reports	• IFRC Vulnerability and Capacity Assessment (VCA) • IFRC World Disasters Report • International disasters databases: * EM-DAT * NatCatSERVICE (Munich Re) * Sigma (Swiss Re)
Strategies	
• National communications to the UNFCCC • National Adaptation Plans of Action (NAPA) for Least Developed Countries	• UN International Decade for Natural Disaster Reduction (IDNDR) • Yokohama Strategy and Plan of Action for a Safer World • UN International Strategy for Disaster Reduction (ISDR) • Hyogo Framework for Action 2005–15
Funding	
• Special Climate Change Fund • Least Developed Countries Fund • Kyoto Protocol Adaptation Fund	• National civil defence/emergency response • International humanitarian funding (for instance, UN Office for the Coordination of Humanitarian Affairs (OCHA) • Multilateral banks • Bilateral aid

Figure 18: Integrating climate change and disaster reduction. Source: Thomala et al. (2006).

At the global level, the year 2015 marked a turning point with the adoption of three relatively interconnected international frameworks: the Sendai Framework for Disaster Risk Reduction 2015-2030, the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC), and the United Nations 2030 Agenda and the Sustainable Development Goals (SDGs). At the heart of these agreements is the idea of sustainable and equitable economic, social, and environmental development (UNCCS, 2017). The interrelation of these three agreements created the opportunity to establish coherence among international agendas with the power to identify and reduce systemic risks, promote sustainable development, and significantly impact the future of humanity (Handmer et al., 2019).

Handmer et al. (2019) emphasize that the integration of these agendas, with a central focus on sustainable and equitable economic, social, and environmental development, creates links that help identify and reduce systemic risks and promote sustainable development. The text identifies some key areas to be implemented by policies across the three fields. According to the authors, it is necessary to identify synergies and conflicts between political agendas to maximize co-benefits, which requires political cohesion both within sectors and globally. They advocate for in-depth multidisciplinary analysis of risk interdependencies to ensure that the trade-offs in one area do not lead to an increase in risks or problems in other areas. In this way, systemic or cascading risks must be explicitly identified and managed, even though uncertainty must be accepted (and managed). Policies must be flexible enough to adapt to new evidence and circumstances, and the time and resources needed to eliminate uncertainty must be available. Resilience is necessary across all sectors and scales. To this end, efficient integration of reports and agreements is required, including capacities and vulnerabilities of systems in continuous updating and monitoring. This is only possible through the design of guidelines that allow for the aggregation of fragmented data sources into a single report. Systemic risks must be identified and prioritized.

The holistic approach today is hindered by the lack of consensus and clarity about what constitutes a hazard, how we define risk, and the lack of conceptual and practical alignment between the three agreements. The report suggests mobilizing science to improve understanding of risks and reinforce interdisciplinary collaboration to provide countries with a common reference point based on concrete data.

1.7.2 The interpretation of resilience in urban policies

International organizations and governments are increasingly promoting urban resilience as a promising policy to help communities face real and future urban risks (ISDR, 2011). However, for resilience to be effectively implemented, it is essential to translate it into concrete and operational actions.

The way this concept is interpreted directly affects the outcomes of political and administrative processes. According to Boin et al. (2010), resilience can be seen as a paradigm shift, a governance model, or a goal to be achieved, being interpreted in various and sometimes contradictory ways. These three perspectives, however, are not mutually exclusive and can coexist and overlap (Normandin et al., 2019). From this multiplicity of interpretations, resilience has been used to promote specific political agendas and to drive changes in urban governance, particularly towards a more integrated and collaborative approach. This process challenges traditional management models based on compliance, emphasizing the need for greater flexibility, governance networks, and participatory processes in policy formulation.

In the book *Searching for Safety*, Wildavsky (1988) differentiated between prevention strategies, applicable when the probability and consequences of an event can be predicted, and resilience strategies, used when there is uncertainty regarding the probability and impacts of risks. For the author, resilience represents the ability to cope with unforeseen dangers after they manifest, which contradicts the rationalist view that all risks can be monitored, measured, and predicted. This paradigm shift requires the development of new capacities in terms of adaptation, flexibility, and agility.

Boin and Van Eeten (2013) deepened this discussion by establishing the distinction between recovery resilience, also called passive resilience, which focuses on reconstruction and recovery post-crisis, and precursor or transformational resilience, which seeks to proactively reduce risks and vulnerabilities (Normandin et al., 2019). Thus, the central question is not just recognizing the need for resilience but determining when and how to develop it. Resilience can emerge as an adaptive behavior, acquired passively after a crisis, or it can be developed proactively, enhancing the system's ability to face complex scenarios before critical events occur.

1.7.3 Resilience and the Transformation of Governance

Governance has historically been debated as a fundamental concept for decision-making and the structuring of democratic norms and actions. In the 17th century, Thomas Jefferson already stated that "if the people are to trust their government, they must be well informed," highlighting the importance of transparency and access to information in the governmental process. However, the term "open governance" (or simply Governance) only emerged in recent decades, driven by new social and technological demands.

Governance refers to bottom-up processes of participation and negotiation that seek to involve public and private actors in the decision-making process in order to increase consensus in choices. It is characterized by an integrated system of theories and practices, knowledge and experiences, with a horizontal and multiscale functional role, requiring the adoption of innovative and integrated approaches that go beyond traditional disciplinary fragmentation (Barbieri, 2015). The shift to this new form of government—from government to governance—occurred as a result of transformations in the current city, starting in the 1980s, with a decentralization of powers and responsibilities and the affirmation of the subsidiarity principle, which challenged the vertical and hierarchical government model in terms of efficiency (Paddeu, 2010).

This new government model is characterized by a greater degree of cooperation between public actors and private entities (bottom-up), involving participation and negotiation, creating a network of interconnections that involves a plurality of subjects, both public and private, bringing specific and often contrasting interests. Governance expanded beyond government agencies and actors, exploring how social systems govern common natural resources, regulate social conflicts, and understanding a set of interdependent systems and subsystems between ecosystems and social, economic, and political aspects (Torres-Lima et al., 2019). It is a multilateral, political, and social process (Wirtz & Birkmeyer, 2015), which has evolved to encompass different dimensions, including global governance, public governance, corporate governance, community governance, and environmental governance. Open governance, as discussed by Meijer et al. (2019), represents a paradigm shift in public administration, promoting new forms of interaction between governments and citizens.

Despite their conceptual proximity, open governance and collaborative governance are not synonymous. Collaborative governance refers to a process in which various actors—governments, civil society organizations, the private sector, and citizens—collectively participate in decision-making and policy implementation. On the other hand, open governance emphasizes transparency, accountability, and increasing public participation in the decision-making process, becoming a model focused on the democratization of public management.

The implementation of resilience as a public policy requires structural changes in government management models. The traditional model, based on rigid hierarchies and adherence to pre-established norms, has been challenged by the need for greater flexibility and intersectoral collaboration. Furthermore, climate adaptation—often associated with resilience—requires a reflective approach, focused on continuous adaptation and integrated governance (Normandin et al., 2019).

In this context, resilience should be understood in its relationship with systemic vulnerabilities generated by the interdependencies between administrations, productive sectors, and society. Its effective implementation requires the active participation of a wide range of public and private actors, as well as the development of new institutional and adaptive capacities. Collaborative governance, by integrating different powers and interests, strengthens cities' ability to cope with complex challenges and promote urban resilience (Normandin et al., 2019).

In this scenario, international organizations have promoted initiatives to consolidate resilience in urban planning. The United Nations Office for Disaster Risk Reduction (UNISDR, 2012) emphasizes that one of the fundamental pillars for building resilience is the existence of an institutional and administrative structure that fosters cooperation between different departments and external organizations. The social and territorial complexity requires government practices in which top-down actions and bottom-up strategies blend, in a mixed model where network and bottom-up work together (Paddeu, 2010).

The literature on governance highlights the importance of intersectoral and horizontal approaches. Peters (1998) argued that governance should be based on cooperation between different sectors, while Christensen and Lægreid (2007) advocated for the whole-of-government approach as a way to address intersectoral problems effectively. However, the transition to a more integrated and collaborative model faces internal challenges. In many administrations, organizational changes are seen as a threat, as they can undermine resources, power, and autonomy of certain sectors (Normandin et al., 2019).

For resilience to be incorporated as a structuring principle of governance, it is essential for different governmental and non-governmental entities to collaborate, overcoming institutional barriers and promoting greater social participation. Moreover, a long-term perspective must be adopted, as the impacts of resilience policies are not immediate. This is a significant obstacle, given that political and administrative cycles often operate within short timeframes, hindering the continuity and implementation of resilient strategies (Normandin et al., 2019).

Public administrations play a crucial role in building a shared vision, ensuring that decision-making processes take into account collective interest. Several authors point out that active community participation in risk management processes is essential to strengthen resilience. This occurs through the sharing of local knowledge, the development of trust between government and society, and the empowerment of vulnerable populations (Antronico et al., 2020; Almeida et al., 2020).

1.7.4 Challenges and Ambiguities in the Implementation of Resilience

Despite the official definitions of resilience, stakeholders in the process still face difficulties in understanding its ultimate goal, concrete requirements, and the actions necessary to achieve a resilient state. Often, writings on the topic do not provide clear guidelines on the measures that actors should adopt, which leads to diverse interpretations and may result in the appropriation of the concept to justify different political agendas. This multiplicity of meanings leads to confusion and can weaken the effectiveness of resilience as an operationalizable concept.

Resilience can be associated with different spheres, depending on the entity responsible for its implementation. If linked to Civil Protection, it tends to be interpreted as a concept related to emergency response and post-disaster recovery. If associated with physical, social, economic, and environmental factors, it expands into a broader spectrum, involving urban planning strategies and sustainable development. At the community level, resilience depends on strengthening local capacities that allow for avoiding or reducing exposure to risk, resisting adverse impacts, and recovering adequately after a critical event.

Whether adopting a proactive approach, which prioritizes adaptation and vulnerability reduction, or a reactive approach, focused on crisis preparedness, resilience has been used as a means to transform urban governance. However, the paradigm shift remains open (Normandin et al., 2019). The rationalist view of urban risk control still prevails in many contexts, resisting the acceptance of the unpredictability of hazards. However, as urban risks become more complex and inevitable, governance models based on avoidance give way to approaches focused on mitigation and adaptation. In this sense, proactive resilience, aimed at adaptation and vulnerability reduction, should be expanded to strengthen the response capacity of cities to emerging challenges.

Based on the transformation of the Governance model, a solution could be the integration of new actors into civil security who work on long-term issues. Alternatively, the civil security community could focus only on reactive resilience, leaving the other community the opportunity to advance in proactive resilience. This cultural shift will need to be supported by leaders and include a transformation of interests and powers, incentives, and knowledge dissemination (Normandin et al., 2019).

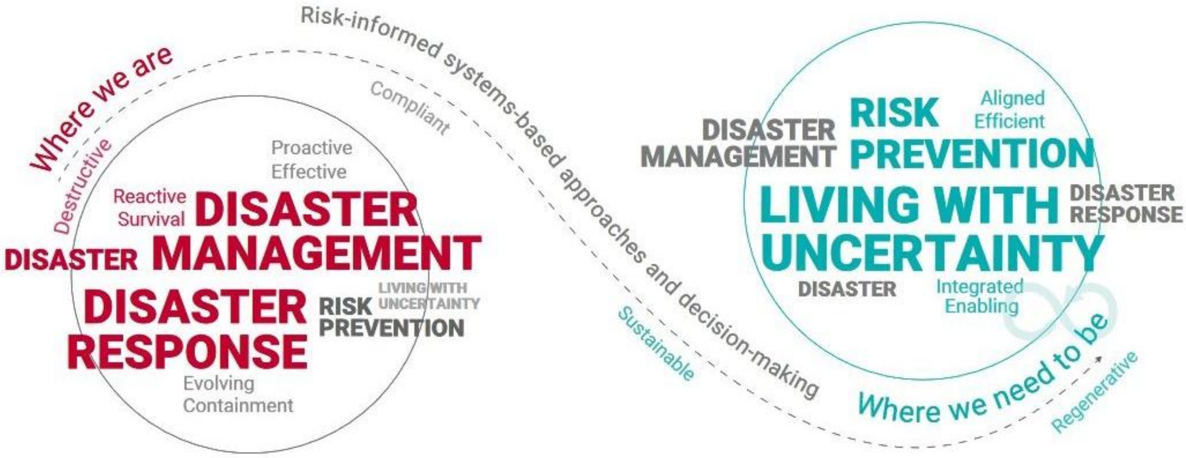

Figure 19: Innovation curve: from destructive to regenerative approaches. Source: UNDRR (2019)

An ideal state or a destination to be achieved.

The great multidisciplinary nature of the concept of resilience means that it has different meanings that intertwine in the discourse and understanding of the actors involved in the development and implementation of policies. The definitions are influenced by different approaches, each focusing on specific aspects of resilience and disregarding others (Normandin et al., 2019).

Resilience can correspond to a state to be sustained by multiple characteristics and capacities, so that the system can declare it upon the arrival of a crisis. Many academic frameworks and organizations propose a set of qualities and resources that must be in place to be resilient. The various indices that aggregate a selection of indicators are an example of this. They are usually based on empirical research that identifies factors supporting organizations' ability to effectively deal with hazards and recover after crises. The problem is that resilience definitions rarely address the underlying assumption that for such "capacity" to occur in a system, its governance components need to be oriented towards processes and outcomes. This would imply a strategy to assess the appropriate level of achievement of these characteristics, followed by a development plan to address deficiencies. Evidence of results that could help define resilience goals is rarely discussed. Resilience outcomes can be identified as reductions in urban risks and vulnerabilities before an event occurs, or they can be seen as an increase in the capacity of municipal actors to coordinate risk management. The latter does not constitute an indicator measuring the resilience of a system but can indicate a pathway to achieving it (Normandin et al., 2019).

One of the challenges is demonstrating the benefits of becoming resilient. If the outcome means that a city experiencing a shock, crisis, or pandemic is able to withstand the event with few measurable effects, it is difficult to prove that the investment was beneficial, as it would measure damage that did not occur.

1.8 Disaster Management

Risk management involves a series of interconnected activities that make up a continuous cycle, ranging from the forecasting of adverse events to recovery after their occurrence (Smith, 2009). This process can be segmented into three distinct phases: before, during, and after the catastrophic event (Pede, 2019).

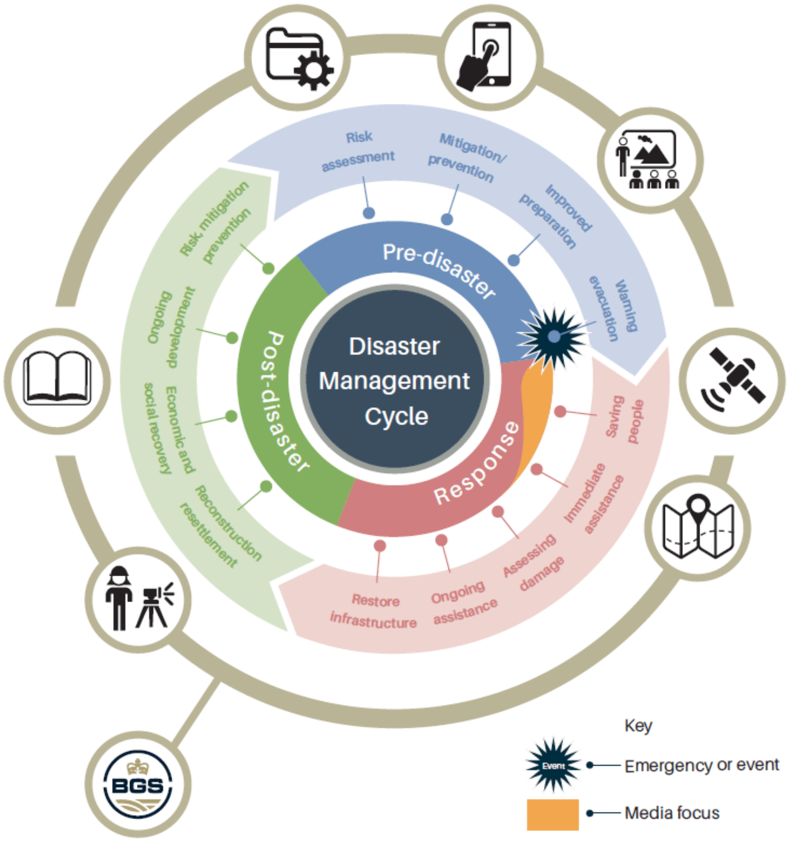

Figure 20: The BGS disaster management cycle shows the complete cycle (and inner circles) of disaster management, as well as a perspective of the types of actions produced by the group through satellite images. Source: https://www.bgs.ac.uk/news/using-satellite-imagery-for-emergency-disaster-response/

The disaster management cycle from BGS shows the complete cycle (and inner circles) of disaster management, along with a perspective of the types of actions carried out by the group through satellite images. Source.

Each of these phases consists of different stages that, when combined, form the so-called PPRR chain—Forecast, Prevention, Response, and Recovery. The forecasting and prevention phase—also called the peace time phase—occurs before the disaster and aims to reduce the vulnerability and exposure of the population and territory to potential threats. During this period, various actors work to mitigate risks, developing territorial planning strategies and promoting community capacity-building to deal with possible emergencies. It is the ideal phase to think about resilience, including a long-term transformative perspective.

During the response phase, which takes place during the catastrophic event, efforts focus on protecting lives, minimizing damage, and coordinating emergency actions to ensure effective assistance to the affected populations. This phase is usually coordinated by Civil Protection and does not allow time or resources for planning; it is a reactive phase.

Finally, the recovery phase extends into the post-event period and is focused on restoring the normal functioning of the affected areas, addressing vulnerabilities that emerged due to the disaster. This stage may involve both physical and economic reconstruction actions and the implementation of measures to strengthen community resilience against specific and recurring events.

The number and type of actors involved in risk management vary depending on the nature of the catastrophe—wildfires, earthquakes, floods, landslides, among others—the spatial scale of the event, and the damages caused to people and property. Some institutions play an active role in all stages of the PPRR chain, while others are involved more sporadically at specific moments.

During the crisis, however, it is possible to distinguish between actors directly involved in crisis management, such as those responsible for emergency operations (Civil Protection), and those who indirectly influence the vulnerability of the territory through strategic development and territorial planning. During periods of normalcy, these actors focus on preventive activities, aiming to avoid or mitigate the occurrence of emergency situations while preparing the community to respond effectively when these situations occur. In urban planning, particularly at the local level, the engagement of the urban planner typically happens in the post-event phase, during reconstruction planning. However, the ideal scenario would be for urban planning for resilience to be built in peace times, finalizing the necessary transformations for a green city, adapted to climate change, and resilient to disasters in the long term.

This risk management framework demonstrates the importance of a systemic approach and the coordination between different scales and sectors, enabling the implementation of more effective strategies to reduce vulnerability and strengthen social and territorial resilience.

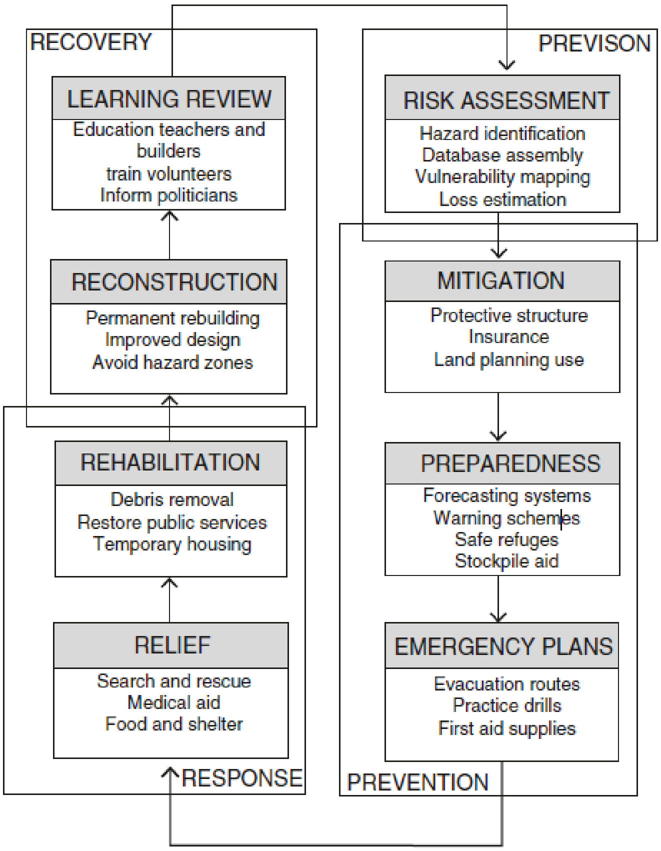

Figure 21: The PPRR chain and its activities. Source: Smith (2009)

Effective risk management depends on the implementation of a structured sequence of actions. Smith (2009) emphasizes that the individual stages of this process often overlap, but it is essential that they operate as a closed loop to maximize learning, experience, and feedback. However, despite the growing recognition of the need for integration and collaboration between different actors in all phases, a truly cohesive approach in the PPRR chain is rarely achieved. As a result, actions related to information, knowledge, and policy formulation often occur in parallel, without meaningful interactions or feedback mechanisms between the different stages (Sapountzaki et al., 2011).

The systemic perspective is essential for understanding disaster management. According to Godschalk (2003), the physical system of a city can be compared to the human body: its infrastructures, road networks, energy, and water supplies are its bones, arteries, and muscles. In a disaster scenario, these systems must continue to operate under extreme stress, as without a resilient physical structure, the city's vulnerability intensifies. However, without a governance system that directs its activities, responds to its needs, and learns from past experiences, the urban system remains fragile. In this metaphor, the brain refers to the city's social and institutional networks, such as schools, neighborhoods, community organizations, and businesses, which must maintain their functionality even under adverse conditions. Thus, urban resilience is not limited to physical infrastructure but also depends on the ability of communities to survive and operate in extreme situations. The adaptive cycle, as defined by Holling (2004), reinforces this perspective by highlighting that complex environmental systems operate under high levels of uncertainty and are constantly affected by ecological, social, and economic impacts. These systems are not static but evolve through continuous learning and adaptation.

However, despite the growing adoption of resilient strategies, the practice still faces significant challenges. One of the main problems is that resilience is difficult to operationalize tangibly, especially when compared to traditional risk management. Currently, much of the actions in this area remain focused on strengthening physical infrastructures to withstand the impacts of disasters, while programs aimed at preparation, forecasting, and community alert receive less attention. To overcome this limitation, it is essential to build strategies based on knowledge, the development of learning capacity, and institutional adaptation (Pede, 2019).

The incorporation of new technologies in the field of risk management also presents challenges. Traditional techniques are largely based on quantitative data collected from past events. More recent methods, on the other hand, use advanced approaches such as machine learning, satellite imagery, and spatial analysis tools to support decision-making. However, these techniques face limitations in representing demographic dynamics and the impact of events on small regions, often due to data scarcity, technological limitations, and generalized approaches that fail to capture local specificities. The lack of infrastructure for monitoring is also a common reality at the scale of small municipalities, especially in less developed countries. The high costs of such installations make their widespread deployment unfeasible, excluding areas of lesser occurrence (Penki et al., 2022). In these cases, traditional knowledge is often used to improve the understanding and communication of risk and uncertainty associated with the event for effective disaster management. Technological development aimed at capturing, analyzing, and sharing different types of spatial information and reference data from various stakeholders presents an effective strategy to reduce costs associated with building large infrastructures while addressing challenges related to data inconsistency and scarcity (Penki et al., 2022).

In the context of disaster management in urban areas, significant advances are being made with the adoption of disruptive technologies, such as the Internet of Things (IoT), image processing, artificial intelligence (AI), big data, and mobile applications, which have been widely promoted and utilized (Munawar et al., 2022). Additionally, during natural disaster events, the use of social media platforms like Twitter tends to grow exponentially (Penki et al., 2022).

In this context, disaster management should be viewed as a critical component for mitigating the impacts of natural events, empowering communities to better identify their risks and adopt strategies that reduce their vulnerability. The central challenge is to effectively integrate physical infrastructures and social disaster response mechanisms, promoting an approach that combines structural robustness with institutional and community flexibility. In this way, it is possible to ensure not only the resilience of cities to the impacts of disasters but also their capacity for adaptation and recovery in the face of future threats.

1.9 Governance

1.9.1 Government or Governance?

In the fields of climate policies and environmental management, governance assumes an adaptive character, emerging as a response to ecological and social uncertainties associated with climate change and development in complex, large-scale environmental systems. This approach is based on dynamic self-organization processes, supported by institutional arrangements and contextually relevant knowledge (Folke et al., 2003). Moreover, adaptive governance transcends traditional, centralized conservation models, recognizing ecological complexity and integrating decentralized, participatory paradigms. Different urbanization processes create various scenarios for building social resilience and the adaptability of natural systems in the context of urban governance (Torres-Lima et al., 2019).

The literature on adaptive governance has largely focused on natural resource conservation, local participation, and national-level organizations. However, there is a gap concerning the integration of multiple levels of government and multiscalar urban and territorial systems (Plummer, 2009). To address this complexity, models such as co-management and collaborative governance networks have emerged, emphasizing the need for evaluative mechanisms in multipartite decision-making. Co-management refers to an arrangement in which various stakeholders participate in decision-making through consensus, interacting with government institutions to resolve dilemmas through dialogue and information sharing (Imperial, 2005). Adaptive co-management advances beyond this model by distributing actors across vertical and horizontal scales, incorporating elements such as social learning, continuous monitoring, and the integration of different forms of knowledge in the decision-making process (Torres-Lima, 2019).

In urban settings, resilient governance is shaped by the interaction between actors, physical and ecological infrastructure, and formal and informal institutions (Archer et al., 2014). Adaptive governance seeks to consolidate flexible networks that combine cultural, social, and political units, from the local to the national level. These networks, structured through participatory and democratic processes, promote communication, social learning, shared responsibilities, and the monitoring of results (Torres-Lima et al., 2019). However, one of the main gaps in this field lies in the power relations between the state and social institutions, reflecting cultural and legal differences that influence the management of common goods.

Territorial governance should be understood as an interdisciplinary system, in which theories and practices are combined with technical and political skills. Barbieri (2015) argues that territorial government cannot be reduced to land use and building regulation, as it incorporates broader dimensions, including environmental conservation, the valorization of natural and cultural heritage, socioeconomic development, mobility, and territorial infrastructure. Thus, territorial governance requires rules and procedures that promote resilience, either through urban regeneration policies or by reducing disordered land occupation.

The governmental response must consider the urban and regional scale, promoting collaboration between megacities and small cities, which have distinct geographies, demographic pressures, and vulnerability levels. Integrated territorial planning is essential to strengthen local coping capacity, ensuring the conservation of natural resources and the maintenance of ecosystem services (Torres-Lima et al., 2019). Urban regions must be viewed as dynamic systems that transcend administrative and economic boundaries, requiring macro and micropolitics to interact in a coordinated manner. This perspective challenges traditional public management models, which often fail to integrate social and ecological territories in the formulation of resilient strategies.

In developing countries, urbanization intensifies problems such as deforestation, degradation of natural resources, and changes in rural land use. Many of these transformations occur without a proper understanding of local realities, resulting in inadequate policies that overlook the primary goods-based commercial structure and regional economic dynamics (Sosa-Rodriguez, 2014). Additionally, jurisdictional divisions often create barriers to intermunicipal coordination, hindering environmental and territorial management, especially in periurban areas, where urban and rural dynamics coexist.

Building territorial resilience requires the reformulation of governance structures, both within municipal administrations and in partnerships with external actors, from a long-term perspective. Giaimo et al. (2019) argue that innovation in resilience should follow the subsidiarity principle, provided it is structured in an integrated horizontal process, rather than within a fragmented hierarchical system composed of isolated plans developed by distinct institutions. Resilient governance, therefore, must overcome the challenges imposed by institutional and sectorial limitations, promoting flexible arrangements that allow continuous adaptation to environmental and social changes. Only through an integrated, participatory, and multiscalar approach will it be possible to strengthen territorial resilience and ensure the sustainability of urban and ecological systems.

1.9.2 The integration of urban resilience in land-use planning

Cities are understood as highly complex socio-spatial systems, characterized by extensive and unpredictable feedback processes that operate at different scales and time horizons (Portugali, 2008). This complexity is intensified by rapid urban expansion, one of the main socio-economic transformation processes of the 21st century. In 2008, more than 50% of the global population began living in urban areas—reaching 75% in Europe—and projections indicate continued urban growth in the coming decades, driven by access to resources and increased life expectancy. As a result, cities emerge simultaneously as engines of development and as spaces that concentrate risks and vulnerabilities (UN, 2014).

In this context, accelerated urbanization imposes significant structural challenges, including the need to provide adequate infrastructure, ensure equity in access to urban benefits, and mitigate adverse environmental impacts. Poor management of urban growth can lead to problems such as pollution, environmental degradation, unsustainable consumption patterns, and occupation of risk areas (Zhang, 2016). Additionally, the growing concentration of population and economic activity increases the vulnerability of cities to climate risks and natural disasters, such as hydrogeological, meteorological, and climatological events. These factors are exacerbated by anthropogenic pressures, such as soil sealing, social inequality, and scarcity of energy resources (Brunetta and Caldarice, 2019).

The concept of urban resilience in urban planning is recent but has emerged as a central principle in contemporary strategies for planning and territorial governance. It is related to the ability of cities to adapt and respond to changes, both gradual and abrupt (Alberti and Marzluff, 2004; Pickett et al., 2004). However, its implementation faces obstacles, as the integration of climate protection into urban planning often remains largely rhetorical, without significant progress in practice (Brunetta and Caldarice, 2019).

Numerous compositional strategies for land-use planning foresee a resilience-based approach. According to Carpenter et al. (2005), resilience thinking is essentially a dynamic process that promotes adaptation to risks and uncertainties, transforming crises into opportunities for development. In the context of territorial planning, resilience can be analyzed from three perspectives: resistance to disturbances, return to previous conditions, and transformation in the face of crises (Martin and Sunley, 2015). The latter approach, although more complex, allows for innovation and strengthens the adaptive capacity of communities (Pendall et al., 2010).

The spatial configuration of cities directly influences climate change, becoming a central element in the formulation of adaptive responses within a resilient framework capable of reducing exposure to extreme events, mitigating impacts, and facilitating adaptation of urban systems (Marshall, 2012). Thus, an increasing number of local governments have developed adaptation plans and strategies, recognizing urban resilience as a priority in development and political governance agendas (Howard, 2009). Land-use planning promotes integrated approaches to adaptation and mitigation, through critical reflection on space and place, but also as a regulatory institution that structures the foundations for resilience and territorial governance (North, 1990). This process involves regulatory frameworks and institutional resources, allowing urban planning to act as a mediator of conflicts of interest and as an agent of transformation in urban systems. In this regard, Hurlimann and March (2012) identified six capacities of spatial planning for adaptation:

1. Act and coordinate collective interests.
2. Reconcile conflicting interests.
3. Operate across multiple spatial and temporal scales, integrating different levels of governance.
4. Address changes in environmental and socio-economic circumstances.
5. Serve as a repository of relevant spatial knowledge for public policy formulation.
6. Guide and coordinate future actions, ensuring long-term benefits.

This perspective is also described as requirements for urban resilience, which should, therefore, be understood as a dynamic and coevolutionary capacity, involving urban authorities, civil society, and citizens in an ongoing process of adaptation (Davoudi, 2012). To achieve this, it is necessary to replace traditional "command and control" approaches with methodologies based on the concept of "learning and adapting," facilitating the construction of a shared vision and strengthening information flows and cooperation (Teigão dos Santos and Partidário, 2011).

Despite all these initiatives, gaps persist in traditional planning, which often adopts an anthropocentric approach and ignores the interconnections between ecosystems and the built environment (Schröter et al., 2014). To overcome these limitations, urban governance must adopt more proactive and integrated models, considering the interscalar impacts of decisions on the environment (Coaffee et al., 2018). The transition to more resilient and sustainable cities requires the reformulation of territorial planning as an ongoing and adaptive process. This demands the adoption of innovative approaches and the creation of flexible institutional mechanisms, capable of handling uncertainties and promoting the continuous adaptation of urban systems.

1.9.3 Urban Planning and the Multilevel Governance System

The transition from urban planning to local governance is linked to the adoption of a multilevel system for sharing knowledge and methods, an essential requirement for dealing with the complexity of urban and territorial transformations. Since the mid-2000s, multilevel territorial governance has consolidated in European spatial planning, integrating with the discourse of economic, social, and territorial cohesion (Faludi, 2012). In this context, the sharing of competencies and responsibilities between different levels of governance in the European Union reflects the need for institutional partnerships and intergovernmental collaborations. As highlighted by Gaimo et al. (2019), "no level can tackle the challenges we face alone. Disaster management requires a multilevel structure capable of mobilizing various sources of resilience, expanding the capacity to respond to uncertainties and unexpected events (Adger et al., 2005), recognizing the uniqueness of physical spaces, as well as the interdependence between different environmental components necessary for sustaining human activities (Giaimo et al., 2019)."

Despite the advancements, one of the critical challenges in implementing multilevel governance is the heterogeneity of knowledge systems used by the various actors involved. These differences can create inconsistencies in inter-institutional interactions, making it difficult to articulate joint strategies (Pede, 2019). To overcome these barriers, the acquisition and sharing of integrated knowledge become fundamental elements in building more effective responses to the challenges posed by complex socio-ecological systems. It is necessary to align capacities to create, verify, absorb, and apply new knowledge with a view to increasing the resilience of systems to risks and uncertainties

(Roux et al., 2006). Therefore, strengthening multilevel governance depends not only on regulatory and institutional mechanisms but also on the creation of knowledge and cooperation networks that promote adaptive and sustainable solutions in urban and territorial planning.

1.10 The Problem of Scale

Scale has been identified as one of the main gaps in risk management research and practice, especially regarding the definition and use of indicators for resilience, vulnerability, and adaptation, as well as the multiscalar approach required for disaster governance. According to Cutter et al. (2008), a community can be understood as the totality of interactions within a social system in a defined geographical space, which can range from a neighborhood or census tract to a city, region, or country. However, it is essential to recognize that different communities coexist within these geographical spaces, with subpopulations often exhibiting distinct levels of vulnerability and resilience, which can lead to uneven recovery processes.

The dynamics of a system at a specific scale cannot be fully understood without considering the scalar and hierarchical influences present within the system. Promoting territorial resilience requires a deep understanding of the adaptive cycles that operate in human-environmental systems and the scales at which these processes occur. According to Cutter et al. (2008), the literature on scales of analysis can be classified into two main approaches:

- Global changes – which examine large-scale processes and their impacts on the environment and populations.
- Hazard research – focused on localized and specific events.

While the first approach seeks to reduce global processes to assess their effects at local levels, the second aggregates local information for comparative analyses at broader scales. Although they employ distinct methodologies, both recognize that factors such as wealth impact resilience and vulnerability, with this relationship being measurable in different ways depending on the scale and unit of analysis. Given the complexity imposed by disasters and their unequal consequences, many countries have adopted the principle of subsidiarity in risk management, granting greater normative and managerial autonomy to the local scale, often represented by municipalities. This measure avoids the complexities of integrating distinct realities, yet municipal administrations frequently face technical difficulties, limitations in social capital, and financial resource shortages for conducting vulnerability assessments and developing resilience plans, particularly in less developed countries and small cities. Even when municipalities manage to access funding from higher government levels or intercontinental programs, a lack of coordination among different governmental entities and the absence of clear guidelines can compromise the continuity of processes. Furthermore, the limitation imposed by four-year municipal mandates hinders the implementation of long-term strategies, generating a recurring sense of administrative discontinuity.

In the field of urban and regional planning, the literature suggests adopting nested governance networks to overcome institutional fragmentation, particularly in peri-urban areas. This concept proposes that when a peri-urban area is not under the authority of a regional governmental institution, it is possible to develop coherent territorial governance systems based on spatial scales and functional boundaries, ensuring that local actions align with collaboratively developed regional policies. An et al. (2025) note that certain literature on natural resources and human ecology overlooks the importance of scales in the interpretation of spatial data and territorial governance. Moreover, research on predictive governance has identified the need to consider different institutional and legal contexts regulating the use of common goods, including variations in access rights and the management of natural resources (Ostrom and Cox, 2010). These variations can be classified into three main dimensions:

- Culture and history of territories – which affect perceptions regarding the use and management of common goods.
- Social rights and governance rules – which influence the distribution of responsibilities and decision-making power (Abbot et al., 2007).
- Legal regulations and decision-making – which define administrative boundaries and the applicable governance regimes.

The heterogeneity of resources, users, and institutions can result in unequal distributions of power and responsibilities, directly impacting the management of common goods and territorial resilience. Decision-making power, in this context, is influenced not only by political and economic factors but also by cultural, social, and symbolic capital, which are specific to each community (Boyce, 2007). Peri-urban socio-ecological systems (SES) are characterized by significant legal and administrative diversity, often involving cross-border areas subject to multiple procedures and governmental bodies. These particularities can hinder land-use regulation, compromising the prevention of environmental degradation and deforestation, as well as exacerbating the vulnerability of populations located in risk areas (Torres-Lima et al., 2019).

1.11 The participatory process for resilience

Community participation in the formulation and implementation of public policies is a fundamental principle of democracy, allowing citizens to directly influence decisions that affect their lives. More broadly, participation is a mechanism for exercising power, enabling marginalized groups to claim their rights and contribute to goal-setting, action planning, and resource allocation.

Community involvement is particularly relevant in the context of Disaster Risk Reduction (DRR), especially in urban areas, not only as a democratic right and to ensure equitable resource distribution but also as a methodology for sharing diverse forms of knowledge. Local communities possess detailed knowledge of the risks they face and are often at the forefront during emergencies. Incorporating this knowledge into DRR policies can result in more effective solutions that are better adapted to the specificities of each locality. Participatory models demonstrate that integrating DRR into community planning through centralized focal points reduces overlaps, clarifies responsibilities, and improves policy implementation. Furthermore, including the community in DRR planning and execution strengthens social cohesion and enhances emergency response capacity.

Community preparedness for emergencies involves a set of pre-impact actions that provide human and material resources for effective disaster response. Such participation helps to limit physical and social impacts, increases resilience, fosters the development of individual skills, identifies vulnerabilities and risks, and improves recovery by creating social networks, strengthening interpersonal and governmental trust, facilitating knowledge transfer, and encouraging civic engagement. Lindell and Prater (2003) emphasize that risk mitigation and emergency preparedness are essential for minimizing the physical damages of disasters, while community recovery resources and external assistance can help reduce social impacts.

Participatory urban planning has proven to be a valuable tool for integrating different perspectives and knowledge in the formulation of DRR policies. Participatory design, grounded in Citizen Science, seeks to share decision-making responsibilities with all citizens involved in urban transformations. In this way, decision-making is not limited to those holding formal positions of power but includes the active participation of various sectors of society, contributing resources and layers of knowledge (D'Onofrio, 2016). The outcome is not a one-size-fits-all solution but rather a common foundation for discussion and negotiation, requiring changes in the traditional approach to urban planning and in how institutions engage with citizen participation.

When addressing complex socio-ecological issues, researchers, policymakers, and social actors must consider multiple perspectives. Although each field of knowledge has its own approaches and parameters, relying exclusively on a single perspective may be insufficient for formulating effective strategies. The integration of different disciplines and sectors is essential to prevent overloads and ensure that the limitations and opportunities of each field are adequately considered in the decision-making process (Buschbacher, 2014).

3.4.2 Levels of Participation

Participation can develop in different ways, ranging from the mere dissemination of information to the genuine empowerment of local actors involved. Regardless of the adopted modality, the activation of participatory practices represents a significant sign of openness within public administration, constituting a concrete application of the open government paradigm. This paradigm is based on three fundamental elements: transparency, collaboration, and participation, aiming to strengthen the relationship between institutions and citizens through more inclusive decision-making processes.

When analyzing participatory practices, three fundamental elements must be considered. First, it is necessary to define which actors are involved in the process and what the objective of participation is, meaning the topic being addressed and how citizens are called to interact. Second, the expected outcomes of this involvement must be assessed, that is, the anticipated results and impacts. Finally, it is essential to select the appropriate tools to ensure an efficient process adapted to the specific context.

The Ladder of Participation

In the late 1960s, Sherry R. Arnstein articulated the ladder of participation, codifying various levels of interaction between administration and the population (Lauria and Slotterback, 2021). This ladder illustrates the possibility of structuring participatory processes on a gradual scale, ranging from the total exclusion of all "bottom-up" voices to the complete autonomy of decision-making by the population. The lowest level represents manipulation, while the highest signifies partnership, delegation of powers, and citizen control.

The two lowest levels are (1) Manipulation and (2) Therapy. These are two levels of "non-participation," explicitly designed to replace real participation. Their actual purpose is not to enable people to take part in planning and policymaking but rather to allow those in power to "educate" and "cure" the supposed symptoms of the population. Levels 3 and 4 correspond to a symbolic concession, in which powerless individuals are allowed to listen and express themselves: (3) Information and (4) Consultation. When those in power offer these possibilities to those without power, it allows for awareness and expression, but it does not entail decision-making authority, meaning that the powerless cannot impose their perspective. With participation restricted at these levels, there is no real momentum for changing the status quo. Stage (5) Placation simply represents a higher level of symbolic concession, as the rules grant those without power the opportunity to make contributions, although the final decision-making authority remains unchanged. Climbing further up the ladder, participation reaches (6) Partnership, where those in power engage in negotiations with the community. At the top of the ladder, we find the highest levels: (7) Delegated Power and (8) Citizen Control, in which the community assumes genuine decision-making and management authority.

The ladder of participation forms groups based on decision-making power—or lack thereof—which can also act as a limiting factor. Within the same group, multiple actors often hold differing opinions, diverging perspectives, and even form fragmented subgroups. In the field of urban planning, the contemporary reinterpretation of this ladder includes practicable levels of participation for spatial projects and urban policy development. These levels can be organized into four main categories:

- *Information*: At this most basic level of participation, public administration provides objective and balanced information to citizens, enabling them to understand a problem, its alternatives, and possible solutions. However, analyses, assessments, and decisions have already been made by the responsible entity, and citizens merely receive communication regarding these deliberations. This is a unidirectional relationship, without genuine dialogue or interaction.

- *Consultation*: In this modality, the relationship between actors becomes bidirectional. Public administration seeks to collect ideas, comments, and suggestions from the population before making a decision. Although citizens have the opportunity to influence choices through the information and opinions they provide, the final decision still remains the exclusive responsibility of the public authority.
- *Collaboration or Co-design*: In collaborative participatory processes, public administration establishes a partnership with citizens, involving them from the initial phases of priority setting. Problem analysis and solution formulation are carried out jointly, and decision implementation occurs in a shared manner, considering the skills, resources, and responsibilities of the various actors involved. This approach establishes a fully bidirectional relationship, where citizens actively participate in all stages of the process.
- *Empowerment:* At the highest level of participation, citizens not only act as partners of public administration but also assume part of the management and decision-making process. In this model, public authorities promote the autonomous initiative of citizens or groups involved in the process, in accordance with the constitutional principle of horizontal subsidiarity. Thus, citizens play an active role and contribute directly to the implementation and enhancement of public policies.

At each level of participation, different configurations emerge, shaped by the dynamic organization of the actors involved, as well as their characteristics and interests. This engagement can vary in intensity and be more or less recognized and addressed, depending on the context. Frequently, groups without decision-making power are included in programs or technical working groups—a practice that can occur at any level of the participation ladder. This inclusion may be legitimate, aimed at expanding representation and engagement, or illegitimate, serving as a strategy for co-optation, conflict mitigation, or even the exploitation of specific skills. In some cases, reports indicate that authorities privately boast about involving marginalized community members solely to weaken their credibility within their own communities.

When administrators, who also hold decision-making authority, are responsible for selecting participants in the process, there is a significant risk of manipulation. This manipulation may involve steering participants toward a predetermined consensus or presenting informational materials that embed value-laden judgments without transparency regarding how those judgments were formed. In such cases, opportunities for questioning and debate are limited, turning participation into a unilateral process. For example, certain urban plans, such as those involving urban renewal, make use of Citizen Advisory Committees (CACs), which, by collecting information or establishing relationships with the public, often serve to legitimize linear and non-reciprocal methods of interaction.

The choice of a facilitator is a crucial element in this context. In some cases, participation is reduced to mere formalities, such as collecting signatures to approve a project that has already been developed, without prior studies of the conditions or needs of the population. In situations where misinformation prevails, citizens may end up signing off on a project without fully understanding its real impact, often favoring private interests, such as construction companies or individuals closely linked to local government administration.

Another problematic practice is the use of consultation as a stand-alone form of participation. When consultation is not accompanied by other participatory mechanisms, it is often superficial, without any guarantee that the opinions collected will have a real impact. Methods such as opinion surveys, neighborhood assemblies, and public meetings are commonly used, but their effectiveness depends on the quality of the questions posed and the rigor of those designing them. Poorly designed surveys can lead to predetermined responses, generating data that do not truly reflect the community's needs.

Regardless of the level of participation adopted, the implementation of participatory practices represents progress in the relationship between government and society, promoting greater transparency and inclusion in decision-making processes. In doing so, public administration not only strengthens its legitimacy but also enhances the quality of the policies developed, aligning itself with more open and democratic governance.

The problem of technical language complexity

One of the main shortcomings highlighted by various authors (Villani et al., 2023) regarding the issue of participation is the low level of community support, driven by the difficulty of the language used by experts in the field. The first step in a resilient city project is to provide communities with reliable information about potential impacts and resilience measures that can be adopted to prevent natural risks from turning into disasters. It is clear that preparedness decisions are not made in isolation. Through community-level discourses and processes, importance is assigned to natural risks and protection measures, helping the population to learn about the subject and supporting public decision-makers through citizen science.

The technical language of urban planning needs to be simplified and made less restrictive to bring citizens closer to territorial governance. Informing citizens about their rights, responsibilities, and options is an important first step in establishing genuine and legitimate participation. However, too often, this is done with an excessive focus on one-way information flow—from decision-makers to those affected by the decisions—without any feedback channels or negotiation power. The most commonly used tools in this unidirectional communication are the press, other media, pamphlets, posters, and surveys. Even public assemblies can become one-way communication vehicles, relying on superficiality as a tool, leaving little room for questions and providing irrelevant answers.

1.11.1 The Actors in Participatory Processes

Citizen participation in decision-making processes is directly related to the principle of subsidiarity, which establishes that decisions should be made at the closest possible level to the people or communities affected, unless a higher level of governance proves to be more effective in managing the issue at hand. Within the European Union context, this principle is recommended to member states as a guideline for strengthening local participation and decentralizing decision-making power. However, the implementation of this principle faces significant challenges, particularly regarding the equitable inclusion of different segments of society in the participatory process (Giaimo et al., 2019). The first question that arises is: who are the potential actors in participation? The intuitive answer would be "all citizens," but in practice, only a small portion of the population is able to actively participate in decision-making processes, which can lead to imbalances in the decisions made. Typically, participation is limited to those who, by inclination or experience, already have a history of engagement, whether through associations, social movements, or personal interest and capacity for action. However, this model presents two opposing challenges. On one hand, there is the risk of excluding the most vulnerable citizens, who face greater barriers to being heard and are often the most difficult to involve. On the other hand, there is the challenge of engaging the most powerful citizens, who may prefer to avoid the public sphere due to lack of interest or to preserve privileges, given that they have alternative means of influencing decisions. This participation paradox—where everyone should be heard, but only a few effectively participate—highlights the need for public administration to be capable of engaging representatives from all sectors, ensuring a diversity of perspectives in the process (Giaimo et al., 2019).

To address this challenge, the literature identifies three main mechanisms for selecting participants: self-selection, targeted selection, and random selection (Fung, 2003). The first mechanism allows any citizen to decide whether or not to participate. This method is widely used in public assemblies as it enables a large number of participants. However, it has two major limitations: 1) low participation rates, as only a fraction of the population is willing to actively engage; and 2) lack of diversity, since participation tends to be limited to those already involved in the issues under discussion, such as political supporters, activists, or groups accustomed to participatory practices. Citizens with family, professional, or business commitments, as well as young people, often exclude themselves. As a result, a forum based on self-selection is unlikely to fully represent all viewpoints within a target population. To mitigate this limitation, it is recommended that processes based on this mechanism first identify interest groups and their representatives, promoting actions to raise awareness and encourage participation.

The second mechanism, targeted selection, seeks to ensure greater representativeness in the process by limiting participation to a carefully chosen group that reflects the interests and perspectives of different sectors of society. In this approach, representatives from trade, professional, business, agricultural, and environmental associations, among others, are invited to participate. This method provides greater diversity of perspectives but also presents challenges, such as the risk that only individuals aligned with public administration are chosen or that representatives prioritize personal interests over the collective interests of the groups they are supposed to represent.

Finally, random selection aims to create a more equitable process by randomly selecting representatives from different sectors of society. While this model minimizes the influence of political interests and ensures greater diversity, it also presents risks, such as the selection of individuals with limited capacity for articulation or insufficient knowledge about the demands of the groups they represent. To avoid this issue, it is essential that random selection be conducted in a stratified manner, ensuring that each population segment is adequately represented.

Since each of these mechanisms has limitations, experience demonstrates that combining different approaches can result in more equitable participatory processes that align with the specificities of each context. Self-selection, due to its potential to attract a large number of participants, is often used in public assemblies and surveys. Targeted selection, in turn, is more common in co-design processes, where participants often have some level of expertise on the topics under discussion or on the methodologies employed. Regardless of the mechanism adopted, participation should be inclusive and accessible to all citizens, providing real opportunities for empowerment at the local level (Normandin et al., 2019).

1.11.2 Knowledge and databases

The participatory process aims to construct a common conceptual space that enables interaction between different domains, considering cultural and social diversity, the pluralism of the professions involved, and the scale chosen for observing phenomena. This approach requires flexibility and dynamism in planning, as well as adaptations in knowledge systems and learning processes, which serve as essential tools for interaction between actors and scales (Pede, 2019). Knowledge, in turn, plays a fundamental role in supporting informed decision-making, as it is related to the processing, interpretation, and understanding of data. The creation of data at different scales and levels must be linked through interactions between these levels to ensure a solid foundation for decisions. In this regard, Wilbanks (2006, p. 4) warns that “a single [level or scale] can frame an investigation too narrowly because the questions and research approaches characteristic of that scale tend to dominate, and because scaling information up and down from other scales requires compromises and often loses information or introduces biases.” Thus, the incorporation of knowledge derived from multiple scales is essential to avoid a limited and potentially biased perspective on the analyzed problem.

However, the production and management of this knowledge face significant challenges, particularly regarding interactions between data owners and users. The main limitations include the absence of data, restrictions on data collection at different levels, and the lack of connection between scales (Gibson et al., 2000). These challenges directly affect the scope and accuracy of the information available for decision-making processes, compromising their effectiveness.

The increasing diffusion of Territorial Data Infrastructures (TDI), encouraged in Europe by the INSPIRE Directive, has promoted advances in the creation and dissemination of digital territorial data, expanding opportunities for planners to use advanced spatial analyses and fostering more transparent and informed decision-making processes (Di Cesare, 2018). However, the implementation of these innovations does not always lead to satisfactory impacts on spatial planning practices. The effectiveness of these guidelines depends on the availability of specific competencies among the professionals involved, as well as on the adoption of appropriate methods and tools to properly operationalize the available information. In this context, the adoption of participatory approaches, such as community mapping and semi-structured interviews, emerges as an effective strategy for improving data collection and understanding local dynamics. These methodologies ensure that the decision-making process considers both the quantitative and qualitative dimensions of data, contributing to more efficient management and the strengthening of community resilience.

3.4.3 Use of Geospatial Information and Technologies

The use of geospatial information technologies (GIS) and open data has transformed the way cities address disaster resilience. Geographic Information Systems enable detailed mapping of risk areas, facilitating the calculation of indicators, the identification of vulnerabilities, and evidence-based decision-making. Successful examples include the open data platform of the city of Christchurch, New Zealand, which has been crucial for post-earthquake recovery by providing citizens and policymakers with accessible and up-to-date information on infrastructure conditions and risks (Munang et al., 2013, p. 50). These tools also play a fundamental role in promoting transparency and public participation. By making detailed information on risks and vulnerabilities available, cities can better engage communities in the co-creation of Disaster Risk Reduction (DRR) solutions, strengthening local resilience. The use of digital platforms and simulation technologies has also been increasingly adopted in cities such as Barcelona and Rotterdam to predict and mitigate disaster impacts (Yildirim & Deniz, 2021, p. 15).

Different countries have approached DRR governance in various ways, reflecting their political structures, levels of development, and exposure to natural risks. A major challenge is the difficulty of visualizing and analyzing complex and highly interconnected issues, such as multi-hazard risks. One of the limitations of informed decision-making stems from the content of the information and how it is presented. Many studies highlight the need to integrate knowledge, emphasizing a holistic perspective to address complex problems and suggesting multidisciplinarity as the solution. However, expert knowledge can vary according to personal experiences, beliefs, and even limitations. For this reason, the knowledge-building process must be based on solid and constantly updated foundations. With the evolution of digital technologies, the accessibility and availability of digital tools, and the shift towards open governance, new global models are emerging in both developed and developing countries (Kanbara & Shaw, 2022), though many local administrations struggle to keep their data updated.

GIScience is a concept that refers to geographic information science, encompassing technologies, methodologies, and applications. Its main fields of study include: Geographic Information Theory, Spatial Modeling, Cartography and Visualization, Acquisition and Quality of Geospatial Data, Spatial and Statistical Analysis, Interoperability and Data Standards, Social and Ethical Impacts, and Technology and Innovation (integration with artificial intelligence, machine learning, cloud computing, and the Internet of Things (IoT)). GIScience is inherently multidisciplinary. GIS enhances traditional cartography, which is still widely used in the public sector, where maps are manually drawn or created using 2D software such as AutoCAD, based on field surveys, satellite data, and aerial photography labor-intensive process prone to human errors. With GIS, cartography has become digital, allowing maps to be created, edited, and shared more quickly and accurately, using technologies such as GPS and remote sensing for geographic and topographic surveys. This has also enabled more complex spatial analyses.

The statistical and spatial analysis tools in GIS allow for the automation of complex processes involving large volumes of geospatial data, identifying patterns and trends that would be difficult to detect manually. Digital storage facilitates data integration and sharing, promoting transparency in public projects. Before GIS, urban planning relied on analog maps and data, which were difficult to integrate visually, limiting the ability to analyze and foresee future scenarios. With GIScience, predictive analyses and scenario visualization can be conducted rapidly, improving and accelerating decision-making. The integration of data from different fields into a common spatial language also makes visualization easier for individuals unfamiliar with spatial representations, supporting participatory urban design projects.

Regarding open governance and community resilience building, geospatial technologies—including Geographic Information Systems, collaborative mapping, and spatial analysis—enable the collection and visualization of data on local vulnerabilities, critical infrastructure, and evacuation routes, facilitating the involvement of multiple stakeholders in risk identification and preparedness planning (Tavares et al., 2011). Furthermore, the use of GIS allows communities to participate more actively and knowledgeably in urban planning and disaster management processes.

The case of Christchurch, New Zealand, in response to the COVID-19 crisis illustrates how the combination of open governance and geospatial technologies can enhance community resilience. After the earthquakes that struck the region in 2010 and 2011, a network of university students, NGOs, local government, and the population created a real-time collaborative online map, enabling affected individuals to access critical information and share their own observations on local conditions. During the pandemic, this open governance model and the use of geospatial technologies allowed the community to quickly organize and respond to emerging needs, demonstrating its capacity for adaptation and transformation (Meijer et al., 2019). These technologies facilitate real-time data collection and analysis, providing an accurate visualization of territorial risks and vulnerabilities. However, Meijer et al. (2019) also highlight challenges related to accessibility and the understanding of these technologies by communities, which can limit effective participation. Digital inclusion and technological education are essential to overcoming these barriers and ensuring that all stakeholders can contribute meaningfully.

Pettit et al. (2019) explores how geodesign and other spatial technologies can enhance collaborative planning. These authors suggest that integrating such technologies with traditional participatory processes can generate more robust and adaptive scenarios, which are crucial for resilient urban planning. A study on risk governance in Germany (Kammerbauer, 2019) reinforces this perspective, showing how an integrated federal structure can coordinate different levels of government and civil society despite coordination challenges.

Although significant advances have been made in understanding and implementing participatory practices in disaster management, substantial gaps remain in the literature. Kanbara and Shaw (2021) discuss the role of science and technology in disaster risk reduction, suggesting that integrating emerging technologies—such as artificial intelligence and big data—with traditional participatory practices is a promising area for future research. Additionally, comparative studies across different geographic and socio-economic contexts could provide valuable insights into the contextual factors influencing the success of participatory approaches. Another gap concerns the long-term assessment of community participation initiatives' impacts on disaster resilience, particularly regarding issues such as equity, inclusion, and the sustainability of implemented solutions (Tierney, 2012; Forino et al., 2015). Furthermore, Forino et al. (2015) identify the need for comparative studies evaluating the effectiveness of different resilience approaches in diverse cultural and political settings. Longitudinal studies tracking communities over time and assessing the impact of participatory interventions on community resilience are also essential for informing future policies.

1.12 Conceptual framework

The expansion of resilience literature since 1992 is not coincidental. The Rio92 Conference and the International Decade for Natural Disaster Reduction set a precedent for disaster studies from a new perspective. However, from 2015 onward, with the development of the Sendai Framework, the 2030 Agenda and its Sustainable Development Goals, and the Paris Agreement in the same year, resilience became imperative, emerging as the key concept for integrating policies on sustainable development, climate change mitigation, and disaster management. The review of territorial and community resilience literature in the field of urban planning has revealed four major areas of interest: Governance, Resilience Scenario Planning, the urgency of a Multi-Hazard Perspective, and the need for Multisectoral Interconnections.

Figure 22: Conceptual framework. Source: Author

Governance
Participation: The effectiveness of resilience depends on the participation and risk awareness of all stakeholders involved, including the government, private sector, and ordinary citizens. For this reason, participation in decision-making is mandatory, as emphasized by the Sendai Framework.
Multidisciplinarity and Diversity: The topic also highlights the importance of multidisciplinarity and diversity in the participatory process, both due to the technical dimensions involved and the need to ensure the representation of each specific sector of the community. This ensures equal opportunities for all voices to be heard and promotes the equitable empowerment of different groups.
Integration of Knowledge: Citizen Science + Traditional Science: The preparedness of governments and communities enhances resilience levels and can be improved through the integration of Citizen Science and conventional science. Some key gaps in this process include the need for equitable communication of procedures, the accessibility and clarity of information and data, and the possibility of empirical experimentation with technical work, particularly within university research groups.
Knowledge in Action: Participation should be capable of informing citizens, increasing their disaster response capacity and preparedness level. However, it should also create pathways for sharing decision-making responsibilities and provide authority for monitoring and evaluating projects and

plans, from their conception to post-implementation assessment. Participation should ensure the engagement of NGOs and associations in these processes.
Data Collection: A major gap in resilience practice is the absence or lack of accessibility to public data. Databases should be accessible and easy to interpret. The lack of data can be addressed through shared strategies involving universities, schools, NGOs, and associations, as well as ordinary citizens through social networks and community mapping initiatives.
Resilient Planning
Building Back Better: Urban projects should support infrastructural, environmental, social, and economic improvements, aiming for an ecological, energy, and digital transition. The objective of transformative resilience should be to view disasters as windows of opportunity—not to return to the pre-disaster state but to create a more resilient, equitable, and sustainable reality by addressing structural, political, and social deficiencies.
Operationalizing Resilience: Moving beyond mere risk reduction and adaptation, resilience should focus on fostering innovation and development. This requires transitioning from theory to concrete actions through long-term plans and projects that can be effectively implemented in real-world contexts.
Local Solutions Connected to the World: Local projects should be designed within broader spatial perspectives, ensuring alignment with regional, national, and global challenges. Urban projects should not conflict with regional structures but rather function as integral components of a larger strategy. Similarly, regional and national databases should be integrated to enhance coordination and data-driven decision-making.
Strategic Planning for Complex Systems: Urban planning must consider cities and territories as dynamic and interdependent systems, where social, economic, environmental, and institutional factors interact in complex ways. This strategic approach requires the application of advanced analytical tools and participatory processes that engage multiple stakeholders and disciplines. Furthermore, planning must incorporate flexibility and adaptability, allowing for continuous adjustments based on the monitoring and evaluation of key indicators. The goal is not only to address immediate needs but also to anticipate future scenarios, fostering resilience, sustainability, and efficiency in resource allocation and decision-making.
Multi-Scalar Interconnection
Integration of Governmental Sectors: The integration of different governmental sectors—including urban planning, environment, transportation, housing, and economic development—is essential for the implementation of effective and coherent policies. This approach aims to overcome the typical fragmentation of public administrations, promoting a systemic and collaborative vision to address urban and territorial challenges. Intersectoral coordination facilitates the alignment of goals, the optimization of resources, and the development of integrated resilience and sustainability strategies.
Horizontal Coordination: Horizontal coordination involves collaboration among different government departments, non-governmental organizations, the private sector, and local communities to promote joint and articulated actions. This approach ensures that decisions are made inclusively and participatively, considering the interests of multiple stakeholders. Horizontal coordination is a key element in addressing complex urban challenges, ensuring that sectoral actions are aligned with common objectives.
Governance Network: Network governance represents a decentralized and collaborative approach in which multiple actors—public, private, and civil society—interact to formulate and implement public policies. This flexible structure allows different sectors and levels of governance to work together in a coordinated manner, fostering innovation and resilience in responses to urban challenges. Governance networks strengthen cities' adaptive capacity by facilitating knowledge exchange, resource mobilization, and the creation of integrated and participatory solutions.
Integration of Databases: The sharing and integration of databases among local, regional, and national institutions are fundamental to grounding urban planning in solid evidence. Consistent and accessible data allow for an in-depth analysis of territorial vulnerabilities and potentialities, supporting informed decision-making and enhancing efficiency in planning and management processes. The interoperability of data systems also improves communication between different governance levels and sectors, contributing to the development of integrated solutions.

Multi-Hazard Perspective

Complex Systems: The challenges of studying complex systems must be addressed through systemic methodologies capable of understanding the interrelations between different types of risks and other variables that impact their causes and effects, such as social, environmental, and economic vulnerabilities.

Integration of Sectoral Policies: The rationalist model of education promotes excessive specialization, which extends to the practice of policies and planning. Each sector conducts its own studies and policies independently, without connections to others. As a result, municipal plans may contain incompatible projects for different types of risks, as they are developed by separate departments. This issue becomes more pronounced as the territorial or governmental scale increases.

Transformative and Proactive Resilience: Transformative resilience goes beyond merely reacting and adapting to risks and disasters; it promotes structural actions aimed at changing the underlying conditions that generate vulnerabilities. This approach views disasters as opportunities to implement systemic changes that strengthen communities, improve social equity, and promote sustainable development. Transformative resilience seeks to anticipate future challenges by integrating innovation, strategic planning, and collaborative governance while encouraging active community participation in shaping solutions for a safer, more sustainable, and inclusive future.

Part 02: REMAP (Resilient and Engaged Multi-hazard Assessment for Planning)

2.1 Participatory Methodologies: Integrating Technical Knowledge and Citizen Science

Public Assemblies, Participatory Budgeting, Surveys, Workshops, Spatial Decision Support Systems (SDSS), Participatory Geographic Information Systems (PGIS), Agent-Based Modeling (ABM), Serious Games, Delphi, Co-Design Frameworks, Multi-Criteria Modeling, and Crowdsourcing Platforms are some examples of methodologies suitable for the participatory process. Without delving too deeply into the explanation of each of these structures and the significant differences they represent for participatory processes, this study identifies Co-Design as the most appropriate framework for the field of urban development.

Co-design fosters a high level of participation, granting stakeholders the ability to propose solutions rather than merely evaluating pre-designed projects. Furthermore, co-design encompasses a variety of techniques, technologies, and design concepts. In this context, the choice of Geodesign is justified by its integration of technical and traditional knowledge, offering a simple and easily understandable visualization model while maintaining the complexity required for in-depth studies. Its structure will be presented in the following section.

2.1.1 The Geodesign

The literature in urban planning presents various paradigms for interpreting the concept of public participation in spatial planning. From the early approaches of advocacy planning proposed by Davidoff (1965) to more recent communication-based models (Innes, Booher 2010), there has been a notable evolution in how participation is conceived and incorporated into planning processes (Khakee, 1998). Different approaches highlight varying perspectives on participation, including the expression of opinions, preferences, and the pluralistic values of communities. Additionally, they emphasize knowledge creation, increased transparency, and broader consensus in decision-making. Higher levels of participation are achieved when citizens are directly involved in formulating possible alternatives and in the decision-making process (Campagna et al., 2016). Thus, the engagement of teams composed of community members becomes essential, particularly in the most critical phases of spatial planning. It is at this stage that knowledge is transformed into action through collaborative design processes and negotiation among different stakeholders.

Geodesign (GD) is a collaborative approach that integrates territorial analysis with the creation of design proposals and the simulation of their impacts (Di Cesare et al., 2016). Developed by Carl Steinitz, GD introduces a new methodological framework for decision-making by integrating tools from geographic information sciences to support the planning of physical land development. Addressing complex problems and deep socio-ecological risks requires that planning and policy decision-making be carried out through a diverse set of disciplines and perspectives, within a systemic thinking approach (Debnath et al., 2022). This integration contributes to overcoming many challenges currently faced in urban and regional planning practices (Campagna & Di Cesare, 2016). Within the GD framework, science and design, technical and local knowledge, are combined to address complex problems related to land use and resource management (Hui et al., 2023). This approach is particularly relevant in the context of Disaster Risk Reduction (DRR) policies and projects, as territories face increasingly complex challenges. In such situations, integrating knowledge from different fields and ensuring the participation of multiple stakeholders in short timeframes becomes indispensable (Nur et al., 2018).

To provide a holistic vision of the territorial context, GD studies are typically conducted by a multidisciplinary team, the Geodesign *Team*. This group includes planners and technical experts, specialists in natural and social sciences, and the local community. During the planning phases, the learning process and negotiation among decision-makers, technical professionals, and stakeholders are facilitated by visualization, modeling, and impact simulation tools derived from geographic information science (GIScience) (Di Cesare et al., 2016). The multidisciplinary team can integrate various urban systems, which is crucial for overcoming the traditional silos between government, academia, and the community.

Although the methodological framework proposed by Steinitz does not necessarily require the use of digital technology, contemporary GD studies integrate geographic information systems (GIS). These systems facilitate data understanding and sharing while enabling the management of complex information, thus contributing to evidence-based decision-making. Additionally, the principles of GD are scalable, meaning they can be adapted to different geographic scales and cultural contexts, allowing for tailored and more effective solutions. The development of Geodesign methods and techniques through GIS has been supported by the increasing dissemination of Spatial Data Infrastructures (SDI) across Europe, following the INSPIRE Directive 02/2007/EC, which has made various environmental digital datasets publicly available. This initiative strengthens GD's ability to integrate geographic data, expanding its reach and applicability in different contexts.

GD offers multiple opportunities, particularly in enhancing public engagement by making technical language more comprehensible and accessible. This improved accessibility facilitates understanding and collaboration among stakeholders, leading to more informed, conscious, and widely accepted solutions. Furthermore, GD fosters interdisciplinary collaboration, which can generate innovative approaches to tackling complex environmental and social challenges by integrating different perspectives and knowledge into a cooperative effort.

On the other hand, methodology also faces critical challenges that may limit its effectiveness. Urban projects often involve conflicting interests among stakeholders, complicating decision-making and requiring careful negotiations and compromises to reach viable consensus. Another significant challenge is the scalability of GD principles, which must be adapted to various scales and cultural contexts. This necessitates flexible and context-specific approaches to ensure that proposed solutions are effective and applicable in diverse situations. Additionally, the availability of georeferenced and non-georeferenced data can be a limiting factor for the scale or informational capacity of the system.

According to Debnath et al. (2022), the increasing frequency of extreme events and natural disasters is placing growing pressure on resilience planning, which must be robust in the face of rising uncertainty. Participatory data-driven methods, such as GD, show significant potential for supporting strategic planning by applying systemic thinking to spatial planning and design. This approach seeks to understand the broader picture of social transformation dynamics in relation to both short- and long-term consequences. GD follows a systems-based approach to analyze human-environment interactions across different spatial and temporal scales.

The Geodesign Framework

To apply this methodological approach to urban and territorial planning, Steinitz (2012) formalized a reference framework called the Geodesign Framework (GDF), structured as a conceptual artifact that identifies potential future transformations of a territory based on existing dynamics. The GDF consists of six fundamental questions, answered through six modeling phases divided into two stages: the evaluation stage and the intervention stage. Despite how it is presented in the figure below, the GDF process is non-linear, allowing the knowledge and information obtained in one phase to be used in subsequent ones in an iterative cycle until stakeholders are satisfied and reach a common decision. Moreover, feedback loops continuously update the information generated at each stage, making the process dynamic and flexible, which is particularly useful for planning complex systems. However, the contribution of GD to resilience planning, as well as the incorporation of disaster resilience thinking into GD practices, has not yet been explicitly explored, representing a gap that future research should address (Debnath et al., 2022).

In the evaluation stage, the first three models describe the current conditions of the study area. This includes: a detailed analysis of the territorial context (Representation Model – RM), a critical reading of ongoing transformation processes (Process Model – PM), and an assessment of the peculiarities, strengths, and weaknesses of the territory (Evaluation Model – EM). In the intervention stage, the last three models aim to predict how the territory may evolve in response to the plan. This stage includes: the design of alternative development scenarios (Change Model – CM), the assessment of the impacts associated with these scenarios (Impact Model – IM), and, finally, the selection of the alternative that best reconciles development objectives with environmental preservation (Decision Model – DM). GDF is both a methodological approach and an organizational system:

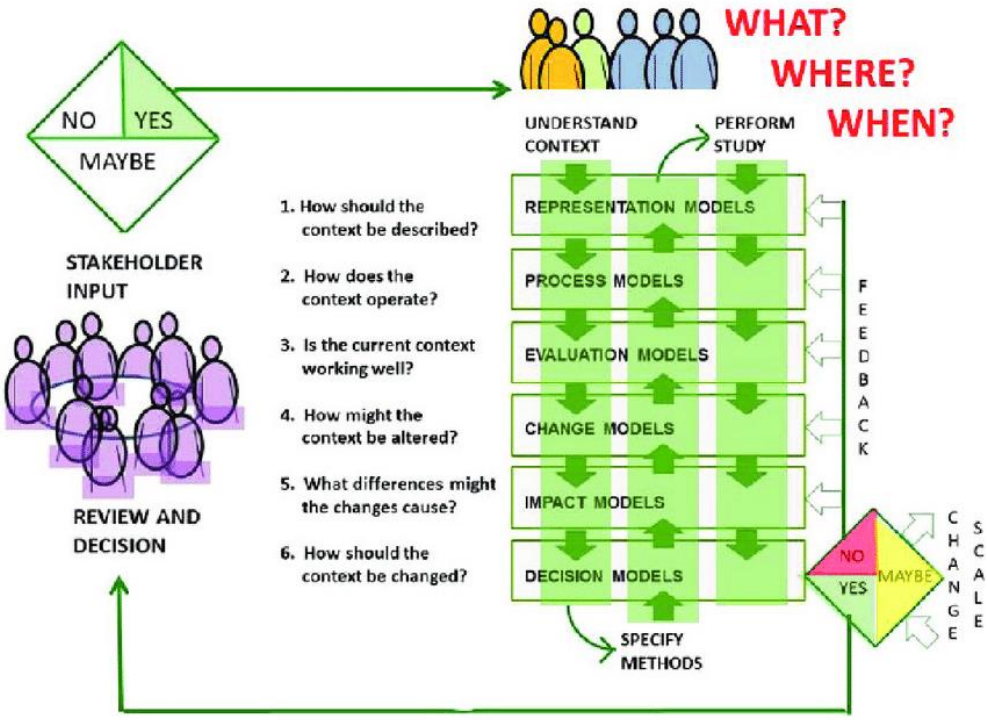

Figure 23: Geodesign framework. Source: Steinitz (2011).

2.2 Best practices for participatory processes

2.2.1 Porto Alegre (Brazil) – The Participatory Budget

The participatory budget constitutes an instrument of participatory democracy, in which the public administration allocates part of the budget to projects defined by the community. The main advantage of this mechanism is that it ensures citizens that their choices will result in concrete actions within a short period.

The pioneering experience of this practice took place in Porto Alegre, the capital of the state of Rio Grande do Sul in Brazil, a large city with approximately 1.3 million inhabitants. The implementation of the participatory budget in the city began in 1989, becoming a milestone in participatory governance policies. This historical period in Brazil was characterized by the context of redemocratization in the late 1980s, when new spaces for participation emerged, expanding society's interaction with public authorities. The 1988 Federal Constitution played a crucial role in this scenario by decentralizing power, allowing municipalities to adopt more open management instruments and direct their own resources (Tartaruga, 2003). Moreover, civil society initiatives emerged to address issues such as land tenure and the lack of urban services and infrastructure, resisting the authoritarian practices then in place.

Sintomer et al. (2013) highlight that participatory budgets have distinct characteristics in terms of institutional design, actual power, and actor inclusion. However, five general criteria are commonly adopted for their implementation:

1. The budgetary aspect must be publicly discussed, addressing scarce resources;
2. Social engagement must occur at the city level, as the neighborhood level alone is insufficient;
3. The process must include repeated instances with clear rules and criteria for participation and budget priority selection;
4. Public deliberation is an essential component;
5. Accountability is mandatory.

The process is organized into regional and thematic assemblies, in which the city is divided into micro-regions further subdivided into thematic groups covering specific areas of public interest, such as health, education, housing, and infrastructure. In these assemblies, the population is informed about the budget proposal, and community representatives discuss investment priorities with municipal technical staff. This format allows for direct interaction between citizens and public administration, ensuring that local demands are heard and considered in budget planning.

In addition to the assemblies, the administration promotes structured public deliberation events, where participants can debate and vote on priority proposals. The organization of the assemblies follows a repetitive structure, adhering to clear criteria and pre-established rules, which contribute to the transparency of the process. Another important aspect is the mandatory accountability mechanism, ensuring that the population has access to the results and the use of approved resources. This methodology not only guarantees the democratic selection of budgetary priorities but also strengthens the role of civil society in monitoring government actions.

In the first year of implementation in Porto Alegre, regional assemblies were organized, during which the population was informed about the budget proposal, and dialogue began between community representatives and municipal technical staff. To facilitate the process, the city was divided into five micro-regions, considering geographical, social, and organizational characteristics. During the assemblies, the budget for the following year was discussed and approved, fostering broad social participation, particularly among the poorest sectors.

The design of participatory budgets in Brazil reflects a more inclusive model, accessible to economically vulnerable sectors. These innovative participation practices differ from traditional mechanisms, such as plebiscites and referendums, by establishing continuous modalities of social influence over public power and the administrative apparatus.

However, ultra-liberal policies have posed challenges to the implementation of participatory and sustainable initiatives. In Porto Alegre, the flexibilization of environmental legislation in favor of agribusiness and real estate speculation has had tragic consequences. Changes to the Brazilian Forest Code, the state Environmental Code, and the city's Plano Diretor de Desenvolvimento Urbano Ambiental exemplify these shifts, whose impacts are felt unequally, primarily affecting the poorest populations. Deforestation and wildfires in the Amazon and Cerrado have altered the rainfall cycle in South America, leading to extreme weather events such as floods. Recently, in Rio Grande do Sul, 10,000 people lost their homes due to climatic events that highlight the costs of permissive and unsustainable environmental policies.

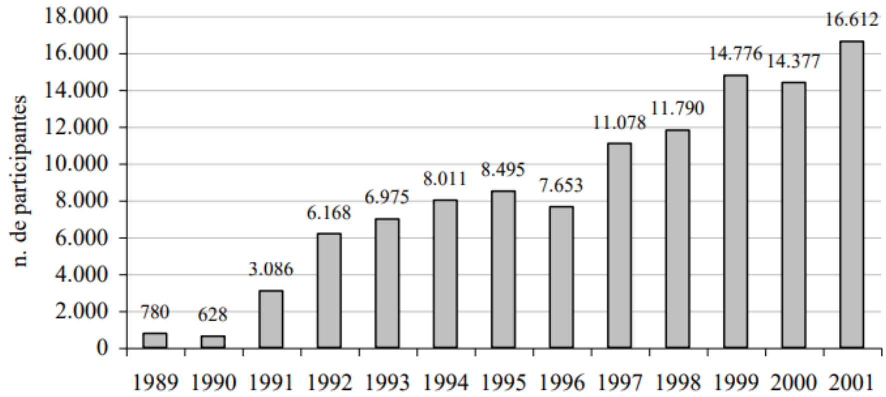

Figure 24: Number of Participants in the Public Assembly of the Participatory Budget of Porto Alegre. Source: Tartaruga (2003)

2.2.2 Bologna

The Emilia-Romagna region has been a national model for citizen participation, standing out in this field. It is the only region in Italy to institutionalize participation as a legal right, with the promulgation of its first participation law in 2010, later revised in 2016 through a participatory process called *Diciamo la nostra* ("Let's Have Our Say"). Regional Law No. 15, of October 22, 2018, establishes guidelines to encourage active citizen participation in the formulation of public policies, fostering collaboration between public administration and civil society. As a result, Emilia-Romagna leads the country in the number of participatory processes: according to the *Osservatorio Partecipazione*, the region has recorded 2,038 participatory processes, while the rest of the country totals 782. The city of Bologna alone accounts for 206 processes listed on the platform.

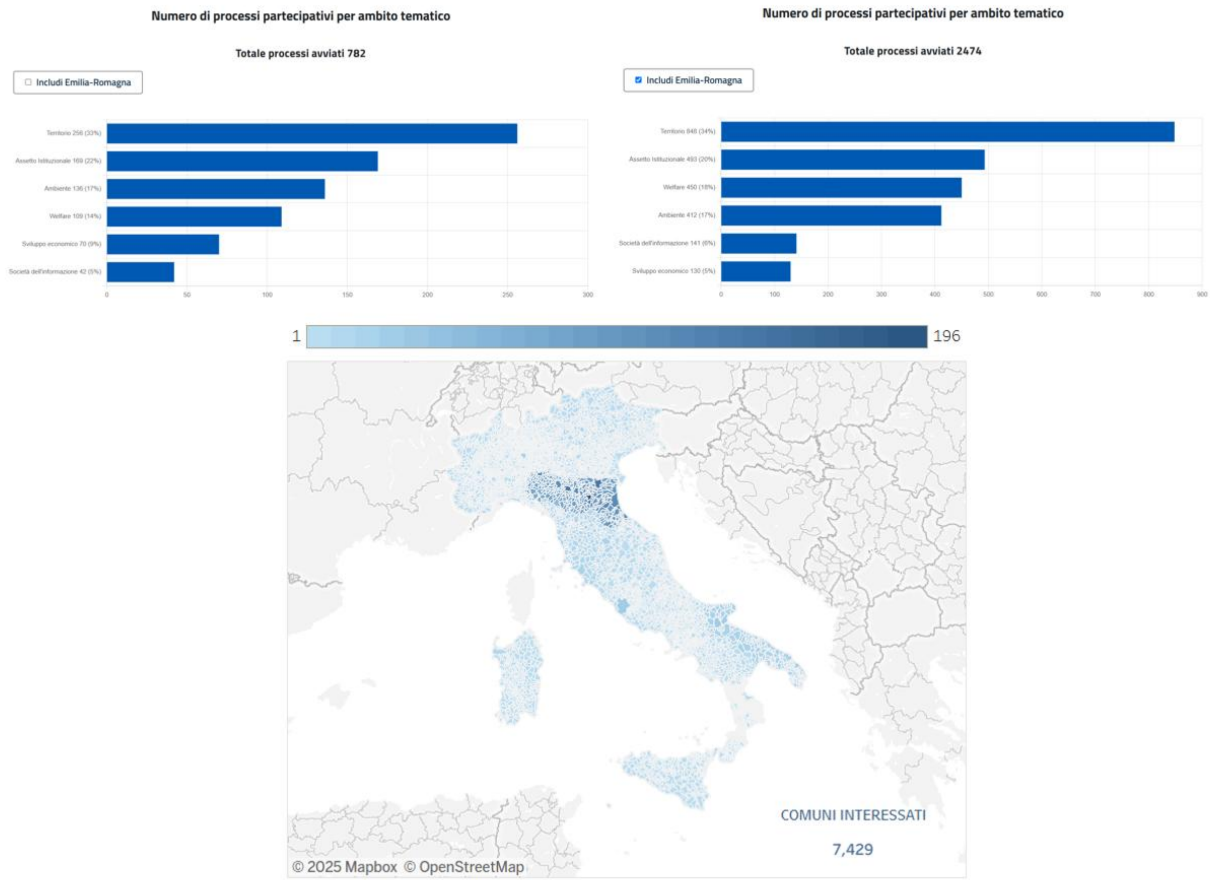

Figure 25: Relation between the number of participatory processes in Emilia-Romagna and throughout Italy. Source: https://www.osservatoriopartecipazione.it/ricerca-processi-nazionali

Bologna has been a pioneer in adopting participatory mechanisms for urban and community management in Italy. Since the 1960s, the city began a process of administrative decentralization, creating a form of “district democracy,” which divided the municipal territory into fourteen neighborhood councils, each representing approximately 30,000 inhabitants. These councils had consultative functions and acted as forums for policy formulation, as well as mediation bodies between citizens and the municipal administration (Martins and Lapa, 2022).

Participation was widely incorporated into urban planning with the 1969 *Piano per il Centro Storico*, which directly involved residents in the rehabilitation of the central area, reconciling cultural heritage preservation with affordable housing provision. The *Peep Centro Storico* of 1973 complemented this strategy by prioritizing social housing in the revitalization of degraded areas. Additionally, Bologna is part of the International Network of Educating Cities, promoting projects that engage children and young people in community decision-making. In the educational sector, the city played a central role in the *Processo di Bologna* (1999), which harmonized European higher education systems, strengthening student and educator participation in academic policy formulation.

More recently, the *Fondazione per l’Innovazione Urbana (FIU)*, a partnership between the Municipality of Bologna and the University of Bologna, has established itself as a multidisciplinary center dedicated to urban research and innovation. The FIU serves as a co-creation space, activating and managing structured participatory pathways focused on specific areas, public spaces, and buildings, fostering collaboration between public administration, academia, the business sector, and civil society, structuring various participatory initiatives such as:

- *Bologna Verde*
- *Laboratori di Quartiere*

- *Bologna Missione Clima*
- *Assemblea Cittadina per il Clima*
- *Bilancio Partecipativo*
- *Radicalmente Adolescenti*
- *Le case di Quartiere di Bologna*
- *Progetto europeo Cities 4.0*
- *Bologna Città 30*
- *Gemello Digitale*

Laboratori di Quartiere

Among these initiatives, the *Laboratori di Quartiere* program stands out, launched in 2017 as part of Bologna's *Piano di Innovazione Urbana*. These laboratories define themselves as democratic spaces accessible to all, fostering collaboration between residents and local authorities in specific areas through a cross-cutting and stable approach. They address themes such as social cohesion, security, and cultural enhancement, activating synergies that enable the experimentation of a new approach to public policies based on proximity. The actions include public assemblies in neighborhoods, thematic meetings, and digital consultations, promoting continuous citizen participation processes aimed at identifying priorities, needs, recommendations, and proposals, while envisioning shared solutions.

In its first year of operation, eleven participatory processes were initiated in selected areas of the city, each with distinct objectives. Various engagement models were also tested, including the participatory budget, applied in six cases through direct voting for public space projects. The investments mobilized totaled 1 million euros for interventions in public spaces, in addition to the allocation of European funds for the recovery of 11 buildings through *Fondi europei PON Metro* (Urban Center Bologna, 2017). Furthermore, priorities were established for education, social and digital inclusion, sports, and culture.

Figure 26: Pathways undertaken by the Laboratori di Quartiere in their first year. Source: https://pianoinnovazioneurbana.comune.bologna.it/laboratori-di-quartiere/

Figure 27: The 12 priorities that emerged from citizen proposals in the Laboratori di Quartiere during their first year. Source: https://pianoinnovazioneurbana.comune.bologna.it/

Participation in Climate Adaptation

In the context of the climate crisis, several Italian cities are developing adaptation plans. Bologna has adopted participatory approaches to formulating mitigation and adaptation strategies. The city has a Bologna Adaptation Strategy Plan (BASP), also known as Bologna Resilient City, developed within the framework of the European Mayors Adapt initiative in 2014. The plan was elaborated within the LIFE+ BLUE AP project, aiming to develop local strategies to strengthen urban resilience to climate change. The city has committed to:

- Assessing climate threats and local vulnerabilities;
- Identifying and prioritizing actions through an adaptation strategy;
- Implementing local adaptation measures;
- Monitoring progress every two years;
- Integrating and enhancing resilience at the municipal level.

The BASP aims to address the city's vulnerability to climate change, particularly in three areas: water scarcity, extreme weather events and hydrogeological risks, and heat waves. It seeks to integrate climate adaptation into the political agenda, involving multiple stakeholders in decision-making and increasing public awareness of climate change effects. The plan consists of a strategic vision, three core objectives, and 12 strategies with 60 actions at both municipal and metropolitan levels (Barbi et al., 2016).

Italy adopts a conforming planning system based on binding zoning and urban development strategies. Since 2008, Bologna has been regulated by the *Piano Strutturale Comunale* (PSC), which defines strategic scenarios, the *Piano Operativo Comunale* (POC) for large urban projects, and the *Regolamento Urbanistico Edilizio* (RUE) for urban development. Following a severe water scarcity crisis, in 2015, the RUE was modified to include stricter criteria for water management, such as the mandatory collection and reuse of rainwater. The POC incorporated BASP guidelines to improve stormwater management in new urban projects (Brunetta and Caldarice, 2019). In this way, BASP integrates with other public policies, covering urban, social, and economic planning.

In 2019, the city declared a climate emergency and, in 2021, incorporated the Citizens' Assembly instrument into the Municipal Statute, consolidating societal participation in defining environmental policies. Subsequently, in July 2022, it approved the implementation procedures in the *Regolamento sui diritti di partecipazione e informazione dei cittadini*. The first Citizens' Assembly for Climate, held in 2023, brought together 100 randomly selected citizens, representing the socio-economic diversity of the city. The Assembly is deliberative, meaning it is based on a method of dialogue and argumentation among the participants. Nine meetings were held, during which participants received logistical support, including a financial allowance of 72.96 euros per meeting and childcare services. The Assembly aimed to define proposals to make Bologna a more sustainable and resilient city, accelerating the energy transition and promoting energy consumption reduction, energy efficiency, renewable energy use, and the creation of energy communities.

The group worked on three main axes:

1. How to promote a fair and equitable energy transition, ensuring the reduction of energy poverty and social marginalization?
2. What strategies should be adopted to mitigate the main climate risks faced by Bologna, such as urban heat islands, floods, and droughts?
3. How to overcome institutional, regulatory, and normative barriers that hinder the implementation of these policies?

The Municipal Council had four months to assess and deliberate on the Assembly's recommendations, in compliance with the provisions of the Municipal Statute. The proposals were debated in three legislative committees, with the participation of a monitoring committee composed of 21 members of the Assembly (Comune di Bologna, 2023). The initiative yielded positive results and led to Bologna's selection for the Cities Mission, a European Commission project aimed at accelerating climate neutrality in 100 cities by 2030, anticipating by 20 years the goals set by the European Green Deal. The project, funded by the Horizon Europe program, allocates 360 million euros (2022-2023) for interventions in sustainable mobility, energy efficiency, and resilient urban planning. The *Bilancio Partecipativo 2023 - Assemblea Cittadina per il Clima* was structured to encourage citizens to submit proposals aligned with this objective, strengthening collaborative governance in tackling climate change. This participatory approach enables communities to be at the center of mitigation and adaptation solutions, reaffirming the city's role as an example of collaborative governance.

Despite the potential of planning for climate adaptation, authors such as Agyeman et al. (1998) and Brunetta and Caldarice (2019) highlight that the integration between national adaptation strategies and local plans remains incomplete. National governments have legal commitments to mitigate climate change, but local governments play a fundamental role in implementing these policies. The plan faces implementation challenges, lacking clear guidelines to define the responsibilities of urban actors and to monitor the planned actions.

Despite progress in incorporating community participation, climate adaptation still needs to be systematized within urban policies, moving beyond isolated responses to vulnerabilities and adopting an approach that integrates adaptive strategies, territorial dynamics, and urban development (Brunetta and Caldarice, 2019). Climate adaptation should be conceived as a continuous process rather than a final desired state, embracing an evolutionary perspective that actively integrates urban authorities, civil society, and citizens in decision-making and implementation.

2.2.3 The Metropolitan City of Cagliari (2021)

Law No. 56, of April 7, 2014, reorganized local autonomies in Italy, establishing metropolitan cities and making the Strategic Plan a mandatory instrument for planning and programming. Before the law, this plan was voluntary. It is designed as a dynamic tool, subject to constant updates and recalibrations, with a focus on intersectoral and multi-scalar development and public participation. However, even though it promotes dialogue among local actors and encourages participation in the formulation of territorial plans, the strategic plan cannot be considered true community-based planning, as it does not necessarily guarantee the direct and meaningful involvement of all local actors (Mundula, 2023).

In the case of the Metropolitan City of Cagliari, the process of drafting the Strategic Plan followed an approach based on strategic rationality (Crozier and Friedberg, 1977). In this model, decisions result from negotiations among multiple decision-makers who seek to maximize benefits and minimize costs. According to Mundula (2023), the formation of temporary coalitions allowed for overcoming competition among different stakeholders, integrating diverse interests. From the outset, the plan was conducted as a participatory process, involving representatives of institutions, associations, businesses, agencies, and citizens, with the interaction of 17 municipalities. In the initial phase, institutional representatives participated in methodological and diagnostic meetings to identify weaknesses, potentials, and challenges of the territory. This process culminated in the first Strategic Forum, marking the beginning of the participatory diagnosis and enabling the communication of the process to citizens while collecting their perceptions.

Subsequently, surveys were conducted through in-person interviews (CAPI) and online questionnaires (CAWI), complemented by thematic roundtables that brought together more than 170 stakeholders. These roundtables discussed six macro-themes: resilience and environmental vulnerability, research and innovation, tourism and economic activities, transportation and sustainable mobility, health and social cohesion, and urban fabric. The collected narratives were used to define key issues, structure the strategic agenda, and formulate project proposals. The next step involved citizen contributions in the form of photos and videos representing the identity of the metropolitan city, complementing discussions from the six co-design laboratories (Living Labs). These activities resulted in 13 systemic actions, integrating 91 interdependent projects prioritized based on strategic impact criteria. The second Strategic Forum validated the shared vision among participants.

The final stage of the process involved international co-design workshops based on Geodesign, titled Future Scenarios for the Cagliari Metropolitan Area. These workshops took place in May 2016 and included a group of 32 participants, composed of university researchers, students, public administration technicians, and independent professionals (Di Cesare et al., 2016). The representation of the study area was structured into 10 systems, categorized between elements of vulnerability (such as cultural assets, natural areas, and hydrogeological hazards) and elements of attractiveness (such as tourism, agribusiness, transportation, high- and low-density residential areas, commerce, industry, and general services). For the development of cartographic representations, data from the Territorial Data Infrastructure of the Sardinia Region (Authoritative Geographic Information – A-GI) were used, and in some cases, data extracted from social media (Social Media Geographic Information – SMGI). Each municipality analyzed its territory and explored how best to geolocate proposals and various policies within the metropolitan context.

The workshops utilized the software Geodesignhub.com, an online GIS-based platform that facilitates both analysis and planning in geographic space. This tool fosters learning and negotiation within multidisciplinary teams, enabling the georeferencing of proposals and the integration of policies. As a result, more than 250 interventions were consolidated into integrated strategic actions, promoting sustainable interinstitutional governance.

Over two days, participants conducted an intensive analysis to evaluate heterogeneous project alternatives related to a highly complex planning process involving multiple actors. Starting from distinct priorities, participants developed alternative development scenarios, which, through consensus-building and negotiation techniques, converged into a single shared final scenario. At the end of the process, five priority actions were defined by the *Consiglio Metropolitano*, representing the shared identity of the metropolitan territory and guiding the next steps for strategic development.

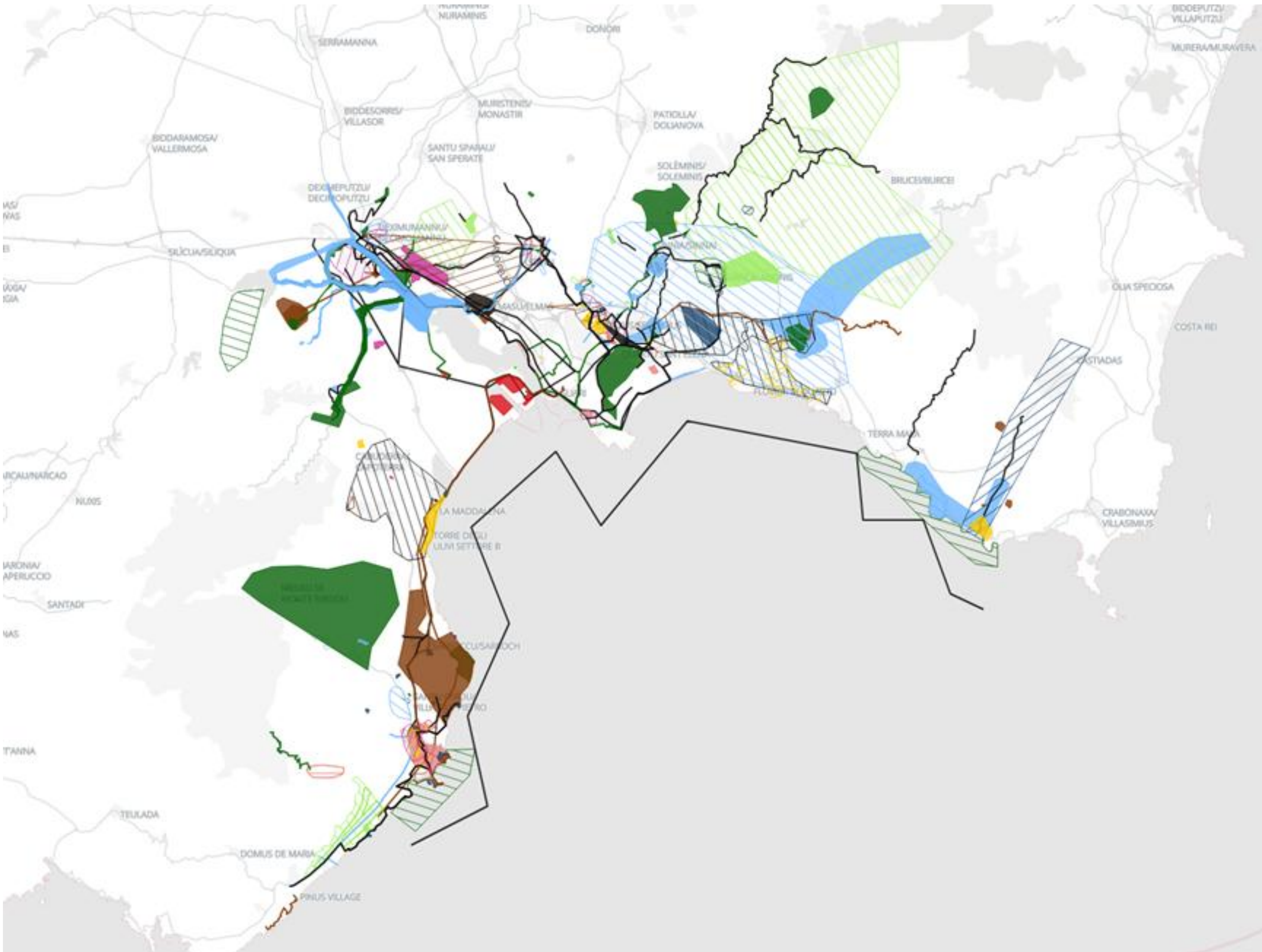

Figure 28: Geodesign Map: Synthesis of Proposals. Source: https://cittametropolitanacagliari.it/portale/page/it/focus_pianostratetico_geodesign?contentId=FGN10220

As a result of the workshop, 91 *schede* of projects were published, consisting of 56 specific projects and 35 cross-cutting policies, as well as the *Atlante di Geodesign*. Furthermore, all the informational assets have been made available in the form of a database accessible through a georeferenced platform.

Figure 29: Number of projects in the Metropolitan City. Source: https://www.cittametropolitanacagliari.it/portale/it/focus_pianostrg_02_03.page

2.3 The Construction of Thought

2.3.1 Methodology Used for the Development of the Tool

The methodology used for the development of the REMAP tool is **Design Science Research (DSR)**, an exploratory approach with a phenomenological stance aimed at producing artifacts or prescriptions based on the understanding of a problem (Santos, 2018; Dresch et al., 2015). This methodology follows these stages: 1) Awareness – problem identification, 2) Systematic literature review, 3) Identification of the problem class, 4) Artifact development, 5) Observation and evaluation of the artifact, 6) Consolidation and extrapolation of the acquired knowledge.

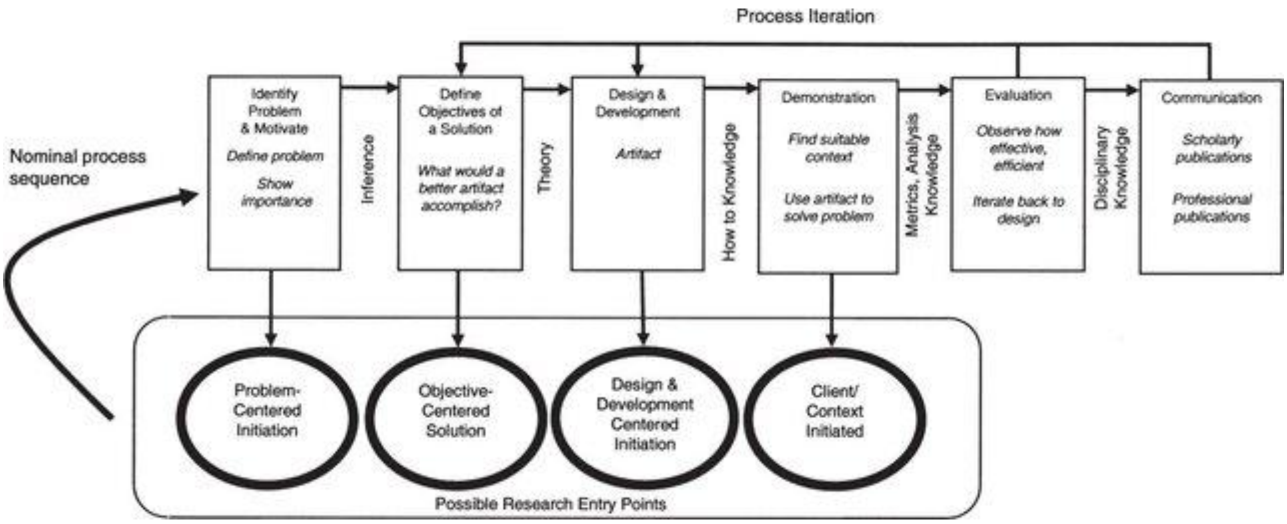

Figure 30: Process model for the Design Science Research methodology.

Based on DSR, the tool was designed to integrate participatory approaches and geospatial tools into urban analysis and planning in multi-hazard contexts aimed at resilience. The methodological framework was divided into distinct yet interrelated phases, with the goal of addressing the research questions and achieving the established objectives.

Thus, after identifying the problem through the state-of-the-art literature review and case studies, and defining the design objectives, the tool was developed and demonstrated, undergoing an evaluation of its effectiveness in an applied case, followed by subsequent refinements. The results will be communicated primarily through this work, and it is expected that the tool may later be useful not only to the academic community but also to stakeholders involved in territorial governance.

2.3.2 Problem Identification: Risk Assessment

The UNDRR office provides technical guidance with specific recommendations on how to comprehensively assess risks and reduce and/or address them through planning. The guidance follows the general workflow for risk assessments outlined in ISO 31000 from the International Organization for Standardization, with its key phases of scoping, risk identification, risk analysis, and risk evaluation:

1. A well-defined scoping phase ensures that the risk assessment supports decision-making and planning, taking into account objectives, targets, values, and the existing policy and planning framework.
2. Risk identification aims to identify relevant risks based on existing knowledge and expert contributions.
3. In risk analysis, risk components (hazards, exposure, and vulnerabilities), their interconnections, cascading impacts, and the potential adverse consequences for selected human or ecological systems are explored and analyzed using quantitative and qualitative methods.
4. Risk evaluation identifies urgent actions and risk reduction measures based on risk tolerance levels defined by communities and key stakeholders.

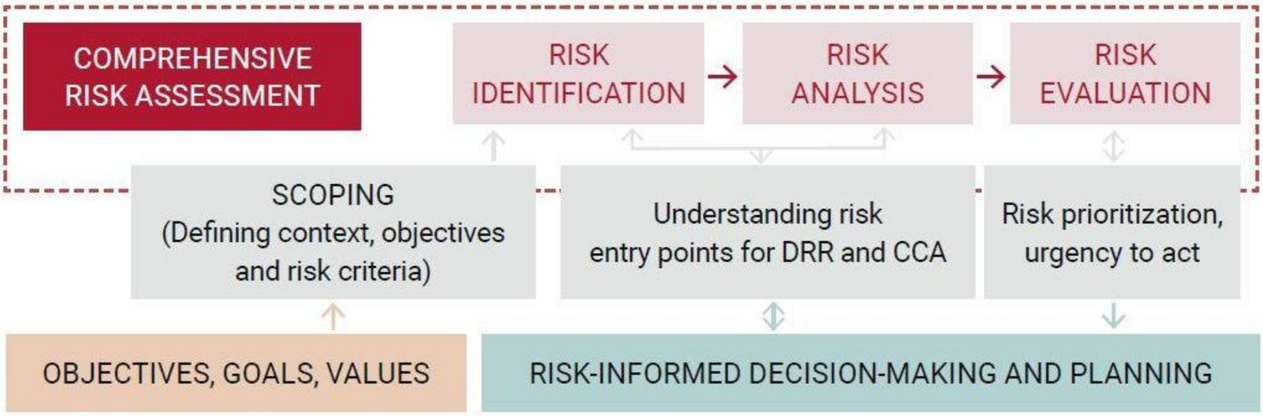

Figure 31: Phases of a Risk Assessment: Technical Guidance on Comprehensive Risk Assessment and Planning in the Context of Climate Change, UNDRR (2022).

According to UNDRR (2022), risk can be assessed both deterministically (through single or a few scenarios) and probabilistically (considering the probability of all possible events). Probabilistic models "complete" historical records by reproducing the physics of phenomena and recreating the intensity of a large number of synthetic (computer-generated) events. As such, they provide a more comprehensive picture of the full spectrum of future risks than what is possible with historical data. Although the scientific data and knowledge used for modeling remain incomplete, as long as their inherent uncertainty is acknowledged, these models can provide guidance on the likely order of magnitude of risks.

In our case, REMAP is a tool designed for creating resilience scenarios at the local level, taking into account multi-hazard risks. To this end, we will use deterministic scenarios based on georeferenced data to determine the physical characteristics of risks and the potential of the territory, as well as vulnerability indicators for social characteristics. Each phase of the study will be based on:

- Social vulnerability assessment by Cutter et al. (2003) for the development of social vulnerability indicators, and

- The methodology of Frigerio et al. (2016) for the analysis and modeling of social vulnerability maps.

For the environmental dimension of resilience, we will use geodesign models to assess the current state and to develop the participatory process model. According to Doost et al. (2025), vulnerability mapping still represents a preliminary and essential step for assessing the resilience of a territorial system. The degree of vulnerability of a territorial system affects its resilience, requiring adaptation measures to improve response and transformation capacity. Indicator-based approaches to vulnerability or resilience assessment have been the focus of most disaster resilience literature over the past 20 years. A wide range of models has been developed, yet, according to Cutter and Derakhshan (2019), few have been empirically tested to evaluate their effectiveness. However, the vulnerability of a community or territory is determined by cultural, social, and economic factors, significantly influencing the impacts of natural disasters. Assessing social vulnerability is essential to understanding a community's capacity to anticipate, withstand, and recover from disastrous events, and vulnerability indicators remain the only viable method for evaluating its social dimension.

According to Doost et al. (2025), "La vulnerabilità (come la resilienza) è una caratteristica specifica di ciascun contesto territoriale e non può essere analizzata con i soli indicatori standard di prestazione (Key Performance Indicator). Pertanto, gli indicatori utilizzati per mappare le vulnerabilità dovranno essere definiti in relazione alle specificità del contesto." Beyond the challenge of selecting the correct indicators for each context and scale, there is an even greater challenge: data availability, particularly at the local level. For this reason, in the Italian context, we follow the recommendation of Frigerio et al. (2016) in choosing indicators that can be represented using demographic data from ISTAT, combined with georeferenced road data in the case of the "accessibility" indicator. This ensures that the results can be easily compared at the municipal level (subdivided by census tracts), as well as at the regional and national levels. The study by Frigerio et al. (2016) discusses a multidisciplinary model for assessing the relationship between environmental processes and social sciences, integrating physical dimensions (seismic risks) and human dimensions (social vulnerability) within the Disaster Risk Reduction (DRR) context. In our study, the physical dimensions will be further expanded to include other resilience-related factors, which will be presented in the following section.

2.4 The REMAP (Resilient and Engaged Multi-hazard Assessment for Planning)

The REMAP framework (Resilient and Engaged Multi-hazard Assessment for Planning) aims to structure the participatory design of scenarios for cities, territories, and communities resilient to multiple hazards, facilitating the integration of technical language and local knowledge for informed and equitable decision-making. The tool can be used by both bottom-up and top-down initiatives, provided they are committed to democratic participation.

FIRST PART: TECHNICAL WORK

Step 1: Defining the Objective

The first step is defining the objective. REMAP is designed for urban and territorial planning, meaning that objectives should focus on the development of project proposals or policies that can be geographically represented. The objectives may involve: 1) Designing spaces more resilient to disasters, 2) Sustainable development, 3) Climate adaptation planning, 4) Land management, 5) Mobility restructuring projects, and other urban planning disciplines.

Step 2: Selecting the Geographic Area

The second step is choosing the geographic area. Projects initiated by public administration typically focus on municipal territories, cities, or even the restructuring of a street. It is important to remember that the choice of scales determines the level of detail and the data selection needed. The smaller the geographic area, the more detailed datasets are required for scenario planning.

1. What geographic area is relevant to achieving the established objectives?
2. Do we have sufficient data for an in-depth study of this area? If so, what are they?

Step 3: Defining the Target Group

1. Who are the people that will benefit from the implementation of this project?
2. Is this a fair decision, or could it reinforce inequalities?
   (If the proposals might increase inequalities, return to the previous steps and reconsider the study area or objectives.)

Step 4: Selecting the Technical Team

The definition of the technical team is crucial for achieving democratic outcomes. The team can be formed through partnerships with educational institutions (universities, technical institutes, research centers, schools) and/or through private sector initiatives (freelancers, studios, laboratories). Interdisciplinarity is key to a successful project. The selected professionals must be capable of meeting the technical requirements for assessing the current state and proposed scenarios. Additionally, it is essential to consider the team responsible for organizing the participatory process, particularly the role of a mediator for negotiations.

1. What is the budget for the participatory process?
2. How much time do we have?
3. What type of material should be produced for analysis according to the objective?
4. What types of professionals are needed, and what is their availability?
5. Who will be responsible for which tasks?

(It is recommended to include at least one professional from the following disciplines: urban planning, architecture, sociology, geology, biology, ecology or botany, public administration, information sciences, civil protection, communication).

Step 5: Defining the Chronogram

At this stage, we evaluate the feasibility of an informed participatory process. The program proposal, time feasibility for each phase, and the budget are analyzed. Additionally, contract modalities and payment schedules are established.

1. What are the stages of the process?
2. How long will each stage take?
3. What is the required budget?
4. What type of contract will be used?
5. When will payment be made?

Step 6: Contracting and Initiating Technical Work

The multidisciplinary team begins assessing the objectives in the study area. The team defines the working methodology, necessary data types, and the responsibilities for various evaluation methods and themes.

First Technical Meeting: Presentation of the project objectives, introduction of team members, and definition of evaluation stages and responsibilities for each phase.

Step 7: Data Analysis and Defining the Data-Sharing Approach

Data include bibliographic collections, legislation and planning documents, demographic data, and spatial data (cartography, cadastral data in CAD, GIS). Below is an example of the types of data used, the available platforms, and file formats specific to the Italian context.

Level	Data	Platforms	Documents
International	International policies and plans	UN, UNDRR, EU	*Sendai Framework, Paris Agreement, Green Deal, New Urban Agenda, Agenda 2030*
	University collaboration or funding	Horizon Europe, World Bank, JRC (Joint Research Centre)	Funded projects on resilience, adaptation, and participatory urbanism
	Georeferenced databases	Copernicus, NASA Earthdata, Global Risk Data Platform (GRID-Geneva)	Satellite data, Global Climate Models, Global risk maps
National	Laws, plans, and financing projects	Ministry websites, ISPRA	*SNAI, PNRR, PNC, Adaptation Plans*
	Demographics	ISTAT	Territorial databases
	Georeferenced databases	National Geoportal, INGV, ISPRA, Ministry of Culture, Ministry of Services	Georeferenced risk data, seismic and hydrological hazard maps, protected areas, cultural heritage
	Specific proposals for resilience or adaptation	Ministry websites, ISPRA, Protezione Civile	Adaptation plans, Resilience and vulnerability indicators
Regional	Laws, plans, and financing projects	Regional websites, *Autorità di Bacino Distrettuale*	*Regional Resilience Plans, Piani Territoriali di Coordinamento*

	Regional urban plans	Regional websites, SIT Regionale (*Sistema Informativo Territoriale*)	*Regional Urban Plans, Territorial Development Strategies*
	Georeferenced databases	Regional Geoportal, SIT Regionale	Thematic maps, Spatial data on risks and vulnerabilities
	Cartographic databases	Regional websites, *Geoportale Regionale*, *Cartografia Regionale*	Cadastral maps, CAD bases, Land-use cartography
	Specific proposals for resilience or adaptation	Municipal websites, *Protezione Civile Regionale*	Adaptation plans, Emergency plans, Risk indicators
Municipal	Laws, plans, and ongoing or completed projects	Municipal website	*PRG, Piani di Emergenza Comunale, Piani di Recupero e Rigenerazione Urbana, Piani di Adattamento*
	Non-implemented proposals	Municipal website, municipal documents	Archived studies and proposals for urban regeneration and resilience
	Databases	Municipal website, SIT Comunale	Cadastral maps, Infrastructure and mobility surveys
	Cartographic databases	Municipal website, Geoportale Comunale	Technical municipal cartography, Zoning maps
	Georeferenced databases	Municipal website, Geoportale Comunale	Vulnerability maps, Spatial data on urban and natural risks

Tabel 1: Suggested Data Collection Model and Platforms for the Participatory Process.

Step 8: Second Technical Meeting – Data Assessment and Identifying Gaps

At this stage, the collected data is assessed, and existing gaps are identified. Strategies are proposed to fill these gaps and process the received data.

One of the main challenges in this process is finding all the necessary data to understand the complexity of urban and territorial systems. Many datasets are inaccessible, costly, or difficult to generate. Some alternatives to bridge this gap include:

- Contracting private companies to provide missing data.
- Using community-based qualitative data collection approaches, such as: Community mapping, OpenStreetMap, Exploratory walks, Surveys and questionnaires.

Given this scenario, the project timeline (chronogram) may need to be revised, incorporating an additional participatory data collection phase, likely requiring an earlier start. Additionally, adjustments may be needed for each phase's duration, the budget, and an overall feasibility analysis.

Step 9: Data Processing to Achieve the Proposed Objective

Each technical sector is responsible for processing the data within its area of expertise. Data must be analyzed in relation to:

- Causes and effects,
- Connections between different scales (regional, national, and international levels).

Creating collaborative research networks is highly recommended. If existing higher-level governmental methodologies or data collection approaches are available, they should be prioritized to ensure data integration and comparability in broader spatial contexts.

Step 10: Selecting the Urban/Rural Systems to Be Analyzed

Once the project objectives have been defined and a review of literature, laws, plans, and projects has been conducted, the next step is to select the systems to be analyzed.

Each system should:

- Represent a key aspect of the proposed objective.
- Consider the geographic scale of the study.

For local disaster resilience proposals, it is recommended to subdivide the analysis into 10 key systems:

1. Green system (natural areas, parks, green infrastructure),
2. Blue system (water bodies, drainage, coastal resilience),
3. Buildings (residential, commercial, industrial structures),
4. Agriculture (farmland, food security, rural landscapes),
5. Cultural heritage (historical sites, protected areas),
6. Tourism (recreational and economic activities),
7. Industry (manufacturing, economic production hubs),
8. Energy (renewable sources, grid infrastructure),
9. Transportation (mobility, accessibility, public transit),
10. SMART system (digital infrastructure, smart city technologies).

For each system, it is necessary to define:

- What elements need to be studied to accurately represent the current state.
- How resilience levels for each system can be measured and improved.

Step 11: Developing the Representation Model

This step involves synthesizing the collected data into a comprehensive georeferenced map that represents the current state of each system.

The Representation Model consists of:

- Georeferenced synthesis maps, aggregating all relevant information.
- Textual reports, including:
- Literature review,
- Cartographic analysis,
- Reviews of past and ongoing projects and plans,
- Ideas and proposals that were never officially voted on by the municipality.

A major challenge in disaster resilience planning is quantifying the social dimension. Since social resilience is difficult to measure, vulnerability indicators are typically used.

If regional or national vulnerability indicators exist, they should be prioritized to ensure comparability at municipal, regional, and national scales.

These data must be:

- Presented in a simple and understandable format for the general public.
- Clearly explain how knowledge was constructed.
- Preferably represented using GIS platforms for quantitative indicator mapping.

Step 12: Developing the Process Model

The Process Model addresses the questions:

- "What is happening here?"
- "What will happen if nothing is done?"

This is a technical model that builds upon the Representation Model to analyze interconnections between system elements in both the present and a future scenario.

The Process Model can be presented in:

- Textual form, with or without scenario visualization.
- Graphical or mapped formats, depending on the available data.

Step 13: Developing the Evaluation Model

The Evaluation Model translates the proposed objectives into a georeferenced map of the study area.

This model integrates:

- Data from the Representation Model,
- Social resilience assessment indicators,
- Technical knowledge of the site,

to define which areas are more or less suitable for achieving the project's objectives within each system.

This Evaluation Model uses a traffic light color scheme to indicate different levels of suitability:

- Red: Areas where the proposed objective already exists and functions well.
- Yellow: Areas that are not suitable for developing the system's objectives.
- Green (gradient of three shades):
- Darkest green: Most feasible areas.
- Medium green: medium feasible areas.
- Lightest green: Least feasible areas.

The technical team evaluates each area's development potential, considering:

- Local needs for development.
- Opportunities and constraints in each area.

In essence, this model functions as a SWOT analysis to assess the strengths, weaknesses, opportunities, and threats of each system within the study area.

Step 14: The Evaluation Model as a Knowledge Exchange Tool

The Evaluation Model plays a critical role in fostering knowledge exchange between technical expertise and local knowledge.

- It serves as the foundation for stakeholder proposals.
- Although it may be contested, it typically represents the most objective analysis of the current situation.
- It functions as a guideline for the project, reducing uncertainty when designing new, unconventional solutions.
- However, transparency is essential:
    - The methodology must be clear and accessible.
    - If a citizen disagrees, they must be able to challenge and discuss the results.

SECOND PART: PARTICIPATORY PROCESS

Step 1: Defining the Chronogram

Establishing the timeline for the participatory process, ensuring feasibility within the available timeframe and budget.

Step 2: Communicating the Process to All Potential Stakeholders Across All Sectors of Society

Ensuring transparent and broad communication to engage all relevant actors in the process.

Step 3: General Questionnaire on the Topic

A general questionnaire on the topic should be distributed to the entire population to create a baseline for understanding public perceptions. The responses guide the proposals toward the majority's interests, reducing the influence of individual aspirations.

Step 4: Selecting Key Stakeholders

It is mandatory to involve at least one representative from each sector of the city. These sectors can be divided by social groups, types of work, or ethnicity. Common representatives include:

- Neighborhood committees
- NGOs
- Cultural associations
- Merchants and industrial representatives
- Environmental movements
- Religious centers
- Foreign communities
- Civil protection agencies
- Public administration representatives
- University and school representatives

Since the co-design process involves a limited number of actors, selecting a representative willing to act as a mediator between the project and their community is essential. These representatives should not act as decision-makers but rather as facilitators of communication.

Step 5: Communicating the Key Stakeholders' Role to the Population

Ensuring transparency by informing the community who their representatives are in the participatory process.

Step 6: Co-Design Workshop

First Meeting

- Presentation of the project proposal, objectives, timeline, and data-sharing platform.

- The platform should contain:
    - Reports from the literature review
    - Full copies of studied plans and projects (both proposed and implemented)
    - Vulnerability maps
    - Synthesis maps representing the current state of each selected system.

To facilitate data visualization, it is recommended to use a specific platform such as: MyMaps, ArcGIS Online (StoryMaps), Mapbox Storytelling. These platforms allow layered visualization, enabling both comprehensive synthesis views and individual layers to explore the construction of each system.

Step 7: Study Period for Shared Data and Information

- Recommended duration: no more than 15 days and no less than 7 days.
- This period allows stakeholders to analyze the shared data and prepare for the next steps in the co-design process[2]).

Second Meeting: Field Survey

The field survey is a crucial step in the participatory process. The experience from this study highlights the importance of defining the areas to be visited, especially in cases where the study area is vast, such as a province or a group of cities. The field experience influences participants to prioritize proposals for specific areas, making it essential to carefully select which locations will be visited. The chosen areas should be strategically relevant to the project's objectives and serve as representative examples of the study area's challenges and opportunities.

Third Meeting: Presentation of the Design Platform

In this session, participants are introduced to the design platform that will be used for co-designing proposals.

Recommended tools:

- GeodesignHub (a GIS-based collaborative design platform)
- Hand-drawn designs on printed maps (for participants unfamiliar with digital tools)

This step ensures that all stakeholders have a clear understanding of the tools available for the collaborative design process, enabling effective participation in the next phases[3]).

Step 8: Developing the Change Model

At this stage, participants propose projects that will contribute to the resilience of the study area. These proposals are classified into two categories:

- Physical projects (solid hatching)
- Policy proposals (dashed hatching)

[2] It is a recommendation that takes into account the learning curve and social engagement. Long intervals between stages often lead to higher dropout rates in the process. However, this is an indicative timeframe for municipal-level projects. For projects at other scales, depending on the complexity and stakeholders involved, this estimate may vary.

[3] The Geodesign Hub platform is quite simple and intuitive to use. However, depending on the audience's familiarity with digital tools, hand-drawing on a map may prove to be a more effective approach. In this case, however, it is recommended to include a subsequent step, where technicians digitize the proposals using the platform or a similar tool, facilitating visualization and comparison between them.

Each participant presents their individual proposals, which are then collected and prepared for further evaluation.

Step 9: Evaluation Period for the Proposed Projects

- Duration: No more than 15 days and no less than 7 days.
- All stakeholders have time to assess the proposals and provide feedback.

During this phase, the technical team may develop the Impact Model to analyze the potential effects of the proposed projects, particularly in cases where conflicting proposals arise.

Fourth Meeting: Negotiation of Proposals and Development of the Decision Model

- The Decision Model defines the final resilient development scenario based on negotiated proposals.
- Recommended tools:
    - GeodesignHub (a collaborative GIS-based planning tool)
    - Hand-drawn sketches on tracing paper over maps (*carta lucida*) for those unfamiliar with digital platforms.

The negotiation process is conducted by interest sectors:

- If multiple representatives exist for a sector, it is important to select a general representative to facilitate the discussion.

The final outcome is a shared vision that integrates technical knowledge and community-driven priorities, ensuring a balanced and equitable development scenario.

THIRD PART: PROJECT, IMPLEMENTATION, MONITORING, AND EVALUATION

Step 1: Development of the Master Plan or Policy Project

Based on the resilience scenario developed during the participatory process, a master plan or policy project is formulated, incorporating the collectively agreed proposals.

Step 2: Deliberative Assembly – Presentation of the Project Proposal with Voting Rights

- The project proposal is presented to the public, with an open voting process.
- A period for contestation and modifications is established.
- If the number of contestations is significantly high, or if the technical team identifies the need for revisions, the assembly can be repeated as many times as necessary to ensure consensus.

Step 3: Approval of the Project and Presentation to the Community

- Once approved, the project is officially presented to the community.
- The most effective communication channels should be selected to maximize public outreach.
- The full project document must be made available on the municipal website to ensure transparency.

Step 4: Implementation

- The implementation phase will be monitored by citizens.
- Since a resilience project is long-term, it is crucial to meet established milestones within the defined timeframe.
- Any delays or unforeseen events must be clearly communicated to maintain public trust in the government's commitment to the project.

Step 5: Evaluation of the Participatory Process

- The public administration must evaluate the participatory process to identify successes and areas for improvement.
- The findings should be documented to enhance future participatory processes.
- A public evaluation questionnaire should be distributed, allowing citizens to provide feedback on their experience in the process.

Step 6: Final Project Evaluation

- The same type of evaluation conducted at the beginning of the participatory process should be reapplied to assess whether the resilience objectives have been achieved.
- Citizens must also be given the opportunity to evaluate the final project choices, either through:
    - Deliberative assemblies, or
    - Satisfaction surveys.
- The approved project data should be publicly available to facilitate transparency and accountability.

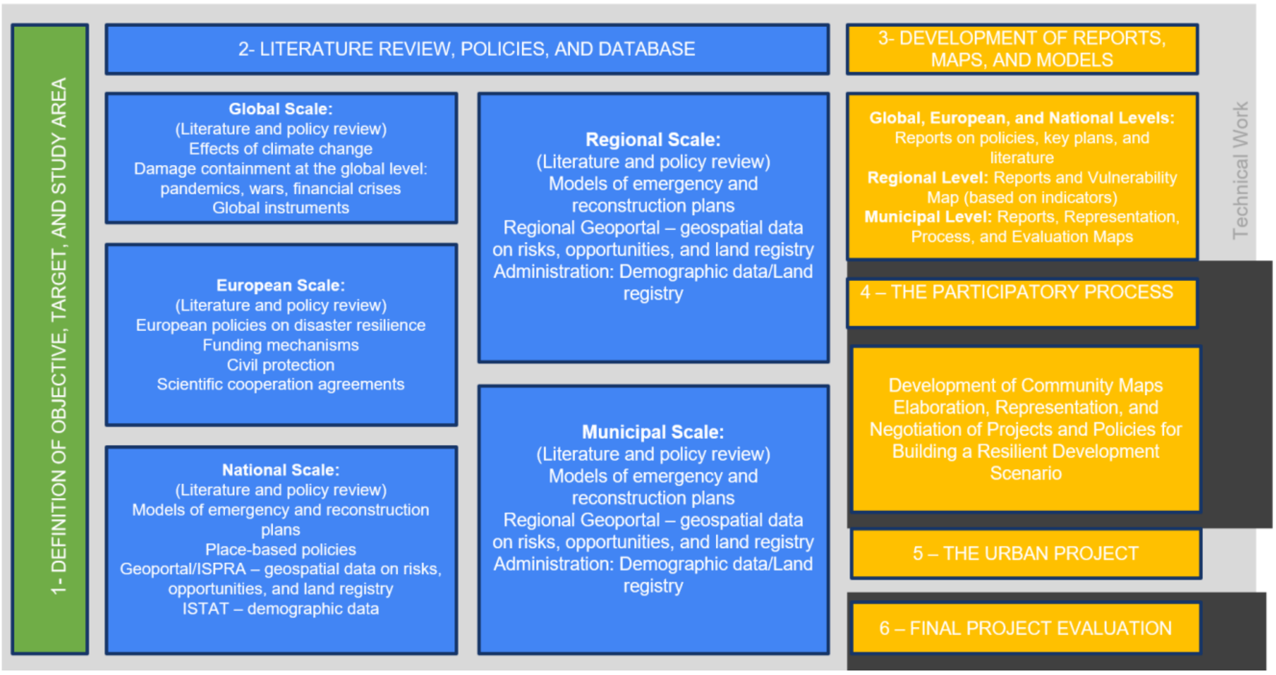

Figure 32: REMAP Organizational Framework. Source: Author

Part 03: Application of the Tool in the Case Study: Central Italy

3.1 What are the inner areas?

Various terms were globally used to describe remote, transitional areas situated between rural and urban settings, such as mountain areas, marginal areas, inland areas, neglected places, hinterland, and countryside, among other similar designations. All these terminologies could describe areas that are very different from each other, but with a common axis of thought: they are marginalised areas around the world with particular difficulties in maintaining themselves and high levels of vulnerability.

Prior to 2012, various terms were used in Italy to describe these remote, transitional areas situated between rural and urban settings, including "*terre alte*", "*aree marginali*", "*aree montane*", "*entroterra*", "*borghi*", "*piccoli centri*", "*aree protette*", and "*aree fragili*". The concept of "inner areas" emerged in the 1990s to refer to the vast territory of the country that is distant from major urban centers and suffers from demographic decline, economic marginalization, and inadequate public services (Staiano, 2020). However, in 2012, the Italian government officially adopted the terminology "aree interne" to refer to these territories (Coni et al., 2020) - areas distant from the major centers of economic development and services but possessing significant natural and cultural resources. It was not until 2014, with the publication of the *Strategia Nazionale per le Aree Interne*, that these areas were officially designated as "inner areas", referring to municipalities located more than 20 minutes away from the nearest service center. This designation made these regions the focus of national policies aimed at enhancing their development potential.

The national classification of internal areas is based on the distance from the centers where essential services are provided. The requirements to be considered a service hub are:

- a hospital with an emergency room (AED level 1)
- a school of higher education
- a silver railway station

All municipalities that do not meet these requirements and are more than 20 minutes away from the service centers are considered internal areas. Subsequently, these areas were redivided, due to distance, into:

- Peripheral areas: 20-40 minutes to nearest center
- Intermediate areas: 40-75 minutes to nearest center
- Ultra-peripheral areas: >75 minutes to nearest center.

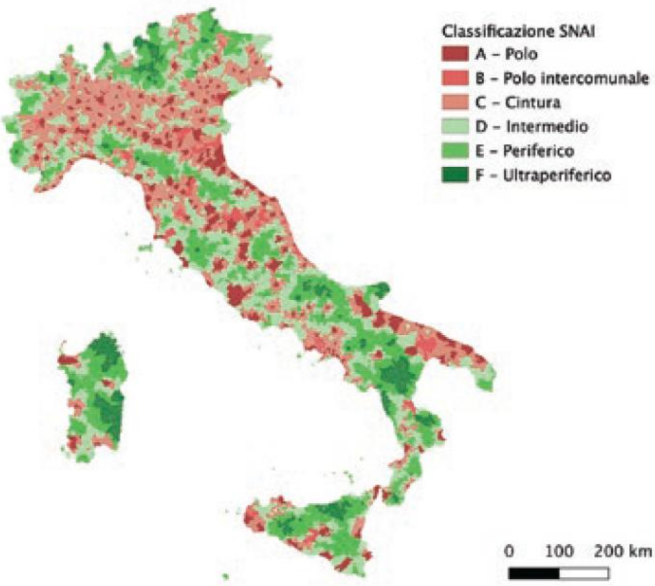

Figure 33: Classification of Italian Internal Areas. Source: SNAI

It can therefore be said that the term "inner areas" reflects a multiplicity of land patterns, landscapes, and types of activities, which can be grouped exclusively based on the criterion of marginalization, instrumentalized as the distance from service centers. This terminology describes only the specific characteristics of the Italian case, which may lead to certain divergences and difficulties in comparison with other academic studies conducted in different countries. The very etymology of the term "internal" suggests a context-specific construction, where fragile and marginalized areas are those located in the internal territory, as opposed to coastal areas. This distinction is a consequence of the urbanization model that emerged after the Second World War, when the country's industrialization attracted residents from rural and mountainous areas to work in factories, large cities, and coastal regions.

3.2 Contemporary Challenges in Inner Areas

3.2.1 Depopulation and Population Ageing

The depopulation of inner areas in Central Italy constitutes one of the main challenges faced by these regions, characterized by a population redistribution process toward large cities and coastal areas (Fenu, 2021). This phenomenon is part of a broader context in which approximately one-third of the European Union's population resides in rural areas, which account for about 90% of the total territory.

The dynamics of rural depopulation can be analyzed from a systemic perspective. According to Mc Donald (2000), this phenomenon began in the post-war period, driven by migration to industrialized cities. This process was accompanied by the progressive abandonment of agriculture, affected both by technological advancements and industrial policies that favored the concentration of agricultural activities in more fertile and accessible regions, to the detriment of marginal lands. This shift particularly affected mountainous areas, which, in addition to being more geographically isolated, became especially vulnerable due to the loss of traditional labor-intensive agricultural practices.

The urbanization process can be analyzed from two distinct perspectives. In developed countries, rapid population growth and the expansion of megacities were observed. In contrast, in Western countries, particularly in Europe, population decline has been accompanied by demographic imbalances across different regions. While large urban centers and coastal areas have experienced significant growth, peripheral, rural, and mountainous regions have faced dramatic depopulation.

The consequences of this population decline are broad and interconnected. The reduction in access to public services and well-being, poor accessibility, lack of economic competitiveness and innovation, as well as fragile governance, which is often fragmented and poorly representative, are both a consequence and an aggravating factor of this process. According to ESPON (2019), the most critical challenges for the future of depopulated regions include low population density, slow population growth, and, in many cases, population decline and aging, issues that are among the key concerns of the European political agenda.

The main causes driving this demographic decline include low fertility rates and emigration, exacerbated by the progressive aging of the population. As an inevitable consequence, the reduction in population density compromises access to essential services, such as healthcare, education, and economic infrastructure, negatively impacting the quality of life in the affected regions.

> "il cambiamento demografico può, infatti, causare un deterioramento della qualità e diversità dei servizi disponibili; un mercato locale debole si traduce in sottoutilizzazione, scarsa manutenzione e in ultima analisi, cancellazione o raggruppamento di servizi. La mancanza dei servizi di interesse generale di base (SIG) erode ulteriormente l'attrattiva delle regioni in contrazione e inizia una spirale discendente di declino. Di conseguenza, fertilità i tassi diminuiscono e la popolazione rimanente invecchia". (ESPON, 2019).

This produces the so-called "spiral of decline" that sees the migration from inland areas of young people seeking professional opportunities or families moved by the search for better educational facilities or simply more opportunities.

> "lo spopolamento fa parte di un circolo vizioso di declino economico e sociale: l’economia decresce, la forza lavoro emigra, c'è una carenza di giovani imprenditori e quindi lo sviluppo di nuove imprese è ostacolato, non c'è massa critica di popolazione per fornire servizi adeguati e questo a sua volta ha un ulteriore impatto negativo sull'attrattiva della regione come luogo di vita e di lavoro” (Crauser, 2011).

Rural areas in the European Union face common challenges related to growth, land use, sustainable development, employment, and accessibility (De Toni et al., 2021). In particular, these areas have a per capita income that is up to one-third lower than the European average, a low female employment rate, and an underdeveloped service sector. These regions have undergone a gradual process of depopulation due to progressive urbanization. The mass migration of young people to urban centers in search of better employment and educational opportunities has resulted in significant population aging in rural areas (Cuccu & Silvestri, 2019). This dynamic has profound consequences for the sustainability of these communities from both an economic and social perspective (Carrosio & De Vidovich, 2022). The aging population exacerbates the fragility of these regions by reducing the available workforce and increasing the demand for healthcare and social assistance services, which are already scarce in these areas. Cuccu and Silvestri (2019) highlight how depopulation has led to the closure of schools, hospitals, and other essential services, making these areas even less attractive to new residents.

3.2.2 Abandonment of Rural and Agricultural Areas

The abandonment of agricultural areas is another critical challenge. As traditional agricultural activities become economically unviable, many lands are left unused or are converted for less intensive uses, such as commercial forests or nature reserves (Carrosio & De Vidovich, 2022). This may seem like a natural evolution, but this transformation has negative consequences, such as the loss of biodiversity, soil degradation, and the increased risk of natural disasters, such as wildfires. Furthermore, agricultural abandonment represents a significant cultural loss. Many of these areas have a long tradition of agricultural practices that are an integral part of the local identity (Cagliero & Corsi, 2013). The loss of these practices weakens social cohesion and also poses a risk to the preservation of knowledge and traditional agricultural techniques, which may be valuable in the transition to more sustainable farming practices.

3.2.3 Connectivity and Infrastructure

Poor infrastructure and digital disconnection are significant barriers to the development of inner areas. Many of these regions still lack efficient public transportation, modern communication networks, and reliable access to high-speed internet (Meini et al., 2017). This limits economic development opportunities, makes these areas less attractive to young people, and prevents the full exploration of their tourism potential. Studies such as those by Cagliero & Corsi (2013) show that the lack of basic infrastructure, such as well-maintained roads, adequate sanitation systems, and accessible healthcare services, compromises the quality of life for residents and discourages new investments. Overcoming these barriers is essential to revitalizing these areas, but it requires significant commitment from both the government and the private sector.

3.2.4 Impacts of Natural Disasters and Recent Crises

Earthquakes and Floods

The inner areas of Central Italy are particularly vulnerable to natural disasters, especially earthquakes and floods. The mountainous geography and seismic faults that cross the region make these events relatively frequent and extremely devastating (Meini et al., 2017). The 2009 earthquake in L'Aquila and the 2016 earthquakes in Marche, Umbria, and Lazio are tragic examples of the impacts these disasters can have, causing widespread destruction and destabilizing local economies.

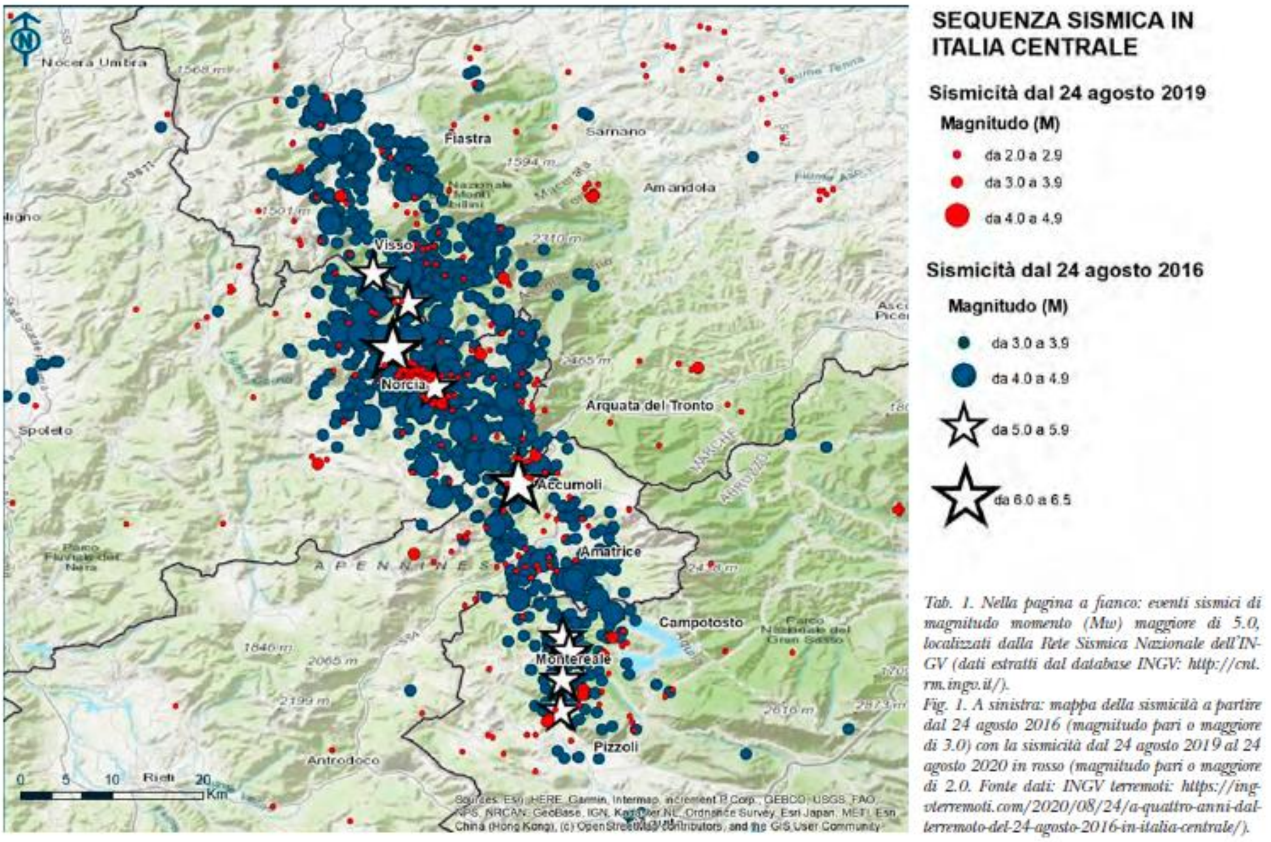

Figure 34: Seismic sequence in Central Italy in 2016/2017. Source: Pierantoni et al., 2022.

These earthquakes not only caused human losses and material destruction but also destabilized the local economy and the social fabric of these communities (Carrosio & De Vidovich, 2022). Marchigiani et al. (2020) discuss the difficulties in rebuilding damaged infrastructure, exacerbated by bureaucracy and lack of resources, which prolonged the recovery process, leading to the abandonment of many areas and the collapse of local businesses. Additionally, floods, which have become more frequent and severe due to climate change, pose a constant threat to the inner areas (Meini et al., 2017). These floods often result in soil erosion, destruction of infrastructure, and significant damage to agriculture. Inadequate water management has worsened these risks, highlighting the urgent need for more effective and coordinated interventions (Epifani & Orso, 2021).

Italy is one of the European countries with the highest likelihood of being hit by a disaster (Frigerio et al., 2018). The seismic risk classification conducted in 2015 reveals that all municipalities are in seismic zones 1 or 2. The area formed by the four regions is rich in cultural resources. It contains UNESCO heritage sites, several historic towns listed as *Borghi più belli di Italia*, as well as numerous properties subject to safeguarding processes. There is significant difficulty in maintaining historic buildings and town centers due to various problems, such as financial difficulties, depopulation, and the subsequent abandonment of these areas, as well as more recent damage caused by the earthquakes of 2012 and 2016. Approximately 70% of Italy is seismically active, but 75% of the building stock does not adhere to modern seismic codes (Marino, 2015).

The analysis focuses on the Apennines of Central Italy, the epicenter of the Amatrice-Norcia-Visso seismic sequence of 2016/2017. It covers four different regions: Marche, Umbria, Lazio, and Abruzzo, and 140 municipalities. The area spans 7,235 km² and has an average population density of 39.5 inhabitants per km², well below the Italian average of 200.8 inhabitants/km². Over 70% of the territory is above 900 meters above sea level. The mountainous nature of the territory creates an uneven distribution of urban areas, with several small centers surrounded by vast rural areas in an isolated landscape, most of which are accessible only by secondary roads.

These territories are distinguished by the sharp dichotomy between their prominent urban centers, including the capital of the country, and the vast marginalized areas identified as "inner areas." The term "inner area" is attributed to these locations due to their significant distance from the centers where essential services are provided, despite the fact that many of them are distinguished by an abundance of environmental and cultural resources, enriched over the centuries by natural diversity and anthropogenic processes.

Their configuration as such dates back to the post-World War II period, when Italy embarked on an intense territorial industrialization process, and its economic growth was both diffuse – occurring in a large number of cities and urban systems – and polarized, as it took place in only a part of Italy's cities and urban systems. This polarized diffusion caused the inner areas to suffer severe economic and demographic decline, alongside a substantial reduction in the use of their territorial capital, understood as natural, cultural, and cognitive capital. Moreover, public policies exploited their natural resources without generating innovation or local benefits.

Since the 1950s, a significant portion of these areas has undergone a process of marginalization, manifested through intense phenomena of depopulation, such as the reduction of the population below the critical level, population aging, and the decline of employment and the use of territorial capital, resulting in the loss of the local supply of public services that define quality of life. Population aging and negative demographic trends led to changes in land use and occupation, resulting in the loss of active land protection and increased hydrogeological risks. Over the last 30 years, there has also been a strong tendency toward the reduction of agricultural land use, accompanied by an increase in forested areas.

Thus, by the late 1980s, after four decades of intense national economic development, Italy was characterized by the presence of a vast mountainous territory almost exclusively composed of small, sparsely inhabited towns with low land occupation and use, few public and private services, hydrogeological imbalances, and degradation of cultural and landscape heritage. Therefore, it can be said that the vulnerability of the territory and its resident communities predates the earthquake and is closely related to the attraction of the population to industrial and coastal areas.

For this reason, it is crucial to view the disaster as an opportunity for change towards an ecological and digital transition that can ensure higher levels of resilience and adaptation to potential future disasters. The post-earthquake reconstruction process must be, from the outset, accompanied and guided by a sustainable development project.

Covid-19 pandemic

The COVID-19 pandemic represented a new type of disaster for the inner areas, which were already vulnerable due to geographical isolation and the lack of quality healthcare services. The pandemic not only exacerbated regional inequalities but also exposed weaknesses in the healthcare system and social support networks in these areas. Additionally, the pandemic reinforced the process of depopulation, as many residents, especially young people, sought safety and better opportunities in large cities. However, Marchigiani et al. (2020) highlights that there was a brief interest in rural regions as safe havens during the pandemic, but this was not sufficient to reverse the long-term structural issues of these areas.

Financial Crisis of 2008

The global financial crisis of 2008 had profound repercussions on the inner areas of central Italy, exacerbating unemployment, reducing disposable income, and accelerating the depopulation process. The economic recession resulting from this crisis deepened regional inequalities, especially in areas that were already marginalized and vulnerable. De Vincenti (2018) and Natali (2016) discuss how the public spending cuts, implemented as austerity measures, further affected these areas, limiting access to essential services and worsening the living conditions of residents (Carrosio & De Vidovich, 2022). This led to a vicious cycle of economic and social decline, from which many communities are still struggling to recover.

3.3 Resilience in Central Italy

In the context of the inner areas of Central Italy, the discussion on transformative resilience, a concept that goes beyond mere recovery, suggesting a reconstruction that promotes positive transformations in ecological, social, and economic terms, proposes that crises, while devastating, can also be seen as opportunities to reconfigure the relationships between communities and their territories, fostering more sustainable and inclusive development. This concept is essential for understanding recent initiatives in the inner areas of Italy, where strategies such as the Strategia Nazionale per le Aree Interne (SNAI) and the Piano Nazionale di Ripresa e Resilienza (PNRR) have been implemented to revitalize these regions. These initiatives not only address the immediate post-disaster recovery needs but also aim to create a foundation for long-term economic development. Regarding geographically based communities and resilience, the concept of community resilience may contain two proxies: urban resilience and rural resilience. Urban resilience emphasizes the ability of cities or urban systems to recover from destruction, while rural resilience aims to maintain a satisfactory standard of living in rural areas.

The cultural landscape of smaller centers in the inner areas

Since the European Landscape Convention in 2000, landscape has been regulated as a cultural, environmental, social, and historical reference, a component of heritage, and a fundamental element to ensure the quality of life for populations. In Article 1 of the European Landscape Convention, signed in Florence on October 20, 2000, under Definitions, paragraph (a) states: "Landscape" means an area of land, as perceived by people, whose character is the result of the action of natural and/or human factors and their interrelations.

The depopulation of smaller historic centers can be interpreted from two perspectives: the abandonment of the entire city for various reasons, or the abandonment of the historic center with the creation of a new peripheral context (Anele, 2020, p.8). Depopulation depends on several factors, often not related to the nature of the place, but to external issues, especially economic and infrastructure related.

The main objective of an urban regeneration project is to recover not only physical objects but also historical memory to bring back to life a hidden place, in which faded relationships are waiting to be reactivated. The peripheralization of urban development dynamics, depopulation phenomena, leads to the degradation of the built fabric, public space, and connections, with an overall loss of meaning and value.

> Pertanto, se da un lato le amministrazioni comunali, e non solo, devono attivare strumenti per rivitalizzare i centri storici interessati da fenomeni di abbandono e degrado, dall'altro le comunità, le categorie professionali, gli operatori economici le associazioni devono riposizionare e orientare i loro interessi verso lo spazio storico o degradato, termini di un binomio che spesso coincidono (Anele 2020, p.11)

3.3.1 Configuration of Internal Areas in the Center of Italy

Central Italy is an area characterized by the presence of small historic villages located in mountainous regions, which have experienced a progressive socioeconomic decline in recent decades (Trizio et al., 2020). The Italian government recognized the need to strengthen the resilience of these vulnerable areas through a multi-risk approach to disaster risk management. Additionally, these are areas of social vulnerability that began in the post-war period due to depopulation and the lack of infrastructure development (Coni et al., 2020). Italy's development model in the post-war period focused heavily on the growth of its major urban centers, leaving the inner areas of the country, particularly in the south, in demographic decline, economic marginalization, and inadequate public services. The country has a clear political and territorial distinction between the north and the south, which leads to the marginalization of the south (which is less industrialized and less developed). This development model, based on industry and large urban centers, attracted the population from the interior and mountainous areas, initially to the large cities and later to coastal areas, causing significant demographic changes. Migration to these areas led to the abandonment of the inner areas, depopulation, loss of income, and population aging. This process has been highly uneven across Italy, primarily influenced by the level of transportation infrastructure development.

The lack of investment and support for these inner areas resulted in a vicious cycle of socioeconomic decline, making them more vulnerable to the impacts of natural disasters. As a result, the inhabitants of these inner regions often lack the resources and capacity to prepare for, respond to, and recover from natural disasters effectively.

The inner regions of Italy have long faced the consequences of natural disasters, particularly following the 2009 L'Aquila earthquake and the 2016 earthquakes in Central Italy. These events highlighted the urgent need to address community resilience and housing recovery in these remote and often underserved areas. The 2008 financial crisis affected the entire world. In Italy, in particular, there was a significant impact, especially in the small centers of the inner areas, where the reduction in the central government's budget led to a reduction in public services such as health and education. Some of the effects of the 2008 crisis persist today, reducing the capacity of local administrations to manage emergencies and investments. Furthermore, the 2009 earthquake in L'Aquila and the 2016 earthquake in Central Italy highlighted the significant challenges faced by these historic cities and villages in responding to and recovering from natural disasters. In 2019, the COVID-19 pandemic further exacerbated the socioeconomic challenges in these regions, as they often lack robust healthcare systems and face increasing difficulties in accessing essential services. The pandemic also had a cumulative effect with the earthquake, delaying the reconstruction process and increasing social and economic vulnerabilities. This complex scenario demands a more nuanced and comprehensive approach to building resilience in Italy's inner regions.

3.3.2 Geography and Economic Structure

The inner areas of Central Italy are characterized by a complex geography, marked by mountain ranges, deep valleys, and a series of small, dispersed communities. These regions, historically dependent on agriculture and small-scale craft production, have experienced a gradual loss of economic power in recent decades. The industrialization and urbanization of large cities attracted young people and the workforce, leaving behind aging and economically fragile communities.

The abandonment of these areas was exacerbated by a lack of infrastructure and disconnection from the country’s main economic centers. The Strategia Nazionale per le Aree Interne (SNAI) was developed to address these challenges, proposing a development model based on local places that recognizes the local specificities and aims to integrate the inner areas into the national economy in a sustainable manner.

3.3.3 History of Challenges and Transformations

Historically, the inner areas have faced a constant population decline due to mass migration to cities and the lack of local economic opportunities. This situation has created a vicious cycle of depopulation, where the departure of young and qualified people further reduced the chances of revitalization in these areas. Carrosio and De Vidovich (2022) emphasize that this trend was exacerbated by national policies that prioritized urban development over rural regions. Depopulation also had a profound impact on the maintenance of rural landscapes and the preservation of cultural traditions. The abandonment of agricultural activities, for instance, led to uncontrolled vegetation growth and increased the risk of wildfires and landslides. Moreover, the reduction in population means that many small towns and villages now face difficulties in maintaining basic services such as schools, healthcare centers, and public transportation.

3.4 Initiatives for Resilience and Sustainable Development

3.4.1 Strategia Nazionale per le Aree Interne (SNAI)

The Strategia Nazionale per le Aree Interne (SNAI) is one of the Italian government's main initiatives to revitalize the country's inner areas. Launched in 2014, SNAI adopts a place-based approach, focusing on the specificities of each territory, with the aim of combating depopulation, improving quality of life and promoting sustainable economic development. SNAI seeks to integrate internal areas into the national economy by enhancing local resources, improving infrastructure and essential services. The plan focuses on four main pillars: health, education, mobility and economic development. It promotes the improvement of essential services, such as schools and hospitals, to ensure that residents have access to quality services, regardless of where they live. Mobility is another focus, with SNAI seeking to improve transportation links between rural and urban areas, as well as digital connectivity, which is essential for integrating these areas into the modern economy.

The SNAI was launched in 2014, during the same period as the European Territorial Cohesion policies 2014-2020. It was drawn up with the aim of guaranteeing the minimum level of aggregate opportunities that allow any citizen, regardless of where they live, to enjoy all the options of choice to live their life to the full and reversing the socio-economic decline of the country's peripheral and remote areas. Through this strategy, the Italian government aims to address the infrastructure gaps, the lack of public services, and the economic stagnation that characterize these areas by promoting local development initiatives based on the valorization of local resources. The strategy provides funding and technical assistance to support tailored development projects in the designated inner areas, with a focus on improving accessibility, strengthening public services, and catalyzing local economic activities.

Once the classification had been completed, SNAI selected some of the internal areas to promote design and policy implementation experiments. The main proposals had a twofold objective: interventions to improve essential services and the development of local development projects, based on territorial capital that is already present but of little expression. There are 72 areas throughout Italy for which European cohesion funds and national funds dedicated to internal areas have been earmarked. Additionally, the Technical Committee for Inner Areas has proposed a plan to foster multipolar interconnections and leverage the unique resources and potential of these territories.

The succes of SNAI in revitalizing Italy's internal regions depends on its ability to foster cross-sectoral partnerships, integrate local knowledge, and tailor interventions to local needs and assets. However, progress has been uneven, with some regions making more headway than others in translating the strategy into tangible improvements in infrastructure, public services, and economic opportunities. The criticism about SNAI is that it could reinforce territorial asymmetries and marginalization, as certain internal areas may be prioritized over others (Staiano, 2020). There are also concerns that the strategy could be used as a vehicle for political patronage, undermining its democratic legitimacy.

However, the implementation of SNAI faces significant challenges, including bureaucracy, institutional fragmentation and the difficulty of attracting private investment. Despite these obstacles, the strategy has achieved notable successes, such as the revitalization of small municipalities and increased tourism in previously neglected areas.

3.4.2 Piano Nazionale di Ripresa e Resilienza (PNRR)

Beyond the SNAI, the Italian government has also launched the Piano Nazionale di Ripresa e Resilienza (PNRR), a comprehensive recovery plan aimed at addressing the country's socio-economic and environmental challenges. Funded by the EU's Next Generation funding package, the PNRR dedicates significant resources to enhancing the digital and green transition, with a particular focus on strengthening primary care services and leveraging telemedicine to better serve remote communities. Specifically, the PNRR allocates €15 billion to healthcare reforms, including investments in bolstering primary care infrastructure and digital capabilities in Italy's internal regions.

In response to the economic crisis caused by the COVID-19 pandemic, Italy has developed the PNRR which includes specific measures to support domestic areas. The plan aims not only at economic recovery, but also at promoting an ecological and digital transition that is inclusive and sustainable. The PNRR allocates significant resources to the development of infrastructure, digitalization and ecological initiatives in the internal areas. This includes building new transportation infrastructure, improving access to high-speed internet and supporting renewable energy projects. The plan also encourages the adoption of sustainable agricultural practices and the enhancement of cultural heritage, with the aim of making the inner areas more attractive to residents and tourists.

Studies such as that by Meini et al. (2017) highlight that although the PNRR offers a unique opportunity to transform inland areas, its effectiveness will depend on the ability to implement projects in a coordinated manner and to involve local communities in the decision-making process. The active participation of communities is seen as crucial to ensuring that PNRR investments result in lasting and positive changes. NextAppennino is a program for social and economic revitalization in the regions of Central Italy affected by the earthquakes of 2009 and 2016, financed by the PNRR Complementary Fund for the "Aree Sisma". It is a financial fund of 1,780,000,000 euros, 700 million of which are available to companies investing in the area.

Italy is currently undergoing a restructuring of its legal framework for emergency management and reconstruction processes. The Dipartimento Casa Italia is the national government institution set up to promote seismic safety and the requalification of building heritage. It focuses mainly on seismic risk prevention, through policies and actions aimed at improving the physical resistance of public and private buildings through the adoption of innovative technologies and resistant materials; urban requalification of urban centers and small towns with particular attention to historical and cultural heritage; support for communities, with technical and financial assistance and through education and awareness-raising. It is the department that coordinates seismic safety projects, manages funds, promotes scientific research and technological innovation and deals with planning and regulations, developing action plans and standards capable of guiding national and local policies towards greater safety and resilience of structures. It is the central point of reference for all initiatives related to safety and quality of living.

The stato di ricostruzione di rilievo nazionale is a special designation applied to areas that have been severely affected by natural disasters, which require particular attention and additional resources for reconstruction. It allows the government to adopt extraordinary and coordinated measures to ensure an effective recovery in the shortest possible time. It aims to recognize the seriousness of the disaster, provide resources and funding, centralized and homogeneous coordination of reconstruction, planning and sustainability in the restoration of affected areas, improving their resilience, as well as special measures (extraordinary legislative and regulatory measures) to speed up the reconstruction process and the return to a state of normality. This last objective could include simplifying bureaucratic procedures, easing building regulations and adopting special urbanization plans. The *Stato di ricostruzione* guarantees the effectiveness of the central government's response, ensuring that resources arrive more quickly, as well as guaranteeing long-term resilience, as it focuses not only on reconstruction, but also on the resilience of infrastructure, helping to minimize future impacts; and facilitates support for communities, their economic and social recovery, helping to restore normality and well-being.

3.5 The vulnerability of the internal areas of the Central Italy

In recent years, the inner areas of central Italy have faced significant challenges stemming from an overlap of crises: a series of economic, social, health and environmental crises. The combination of devastating earthquakes, the 2008 financial crisis and the COVID-19 pandemic has exacerbated pre-existing vulnerabilities, such as depopulation, an ageing population and the abandonment of farmland and historic centers (Carrosio & De Vidovich, 2022).

The IFEL report (2019) shows that rural areas in the EU have a per capita income that is around a third lower than the European average. The internal areas of Italy are characterized by several vulnerabilities that make them particularly susceptible to disasters and challenges in recovering from them. These include:

- Demographic decline and aging population (Marzi et al., 2019) - Many of these areas have experienced consistent population loss, with an increasingly older population that is more vulnerable during emergencies.
- Inadequate infrastructure and transport connectivity - Internal areas often lack modern and efficient transport systems, which can hamper evacuation and relief efforts during disasters.
- Dependence on primary economic activities - The economies of internal areas tend to rely heavily on agriculture, forestry, and other primary industries that can be severely disrupted by natural disasters.
- Limited access to public services - Residents of internal areas frequently face difficulties accessing essential services like healthcare, education, and emergency response, which are crucial in disaster situations.
- Baixa taxa de ocupação feminina (IFEL, 2019)
- Setor de serviços menos desenvolvido que a média europeia (IFEL, 2019)

As highlighted by recent studies, the combination of these factors can severely undermine the resilience of internal areas in Italy, rendering them more prone to the impacts of natural disasters and less able to recover effectively.

4.5.1 Vulnerability assessment

The use of indicators is the most popular strategy for assessing resilience or vulnerability. They are generally used with a quantitative methodology, although some qualitative or mixed experiences have yielded good results in scientific theory. The methods of representing results are varied, including the use of reports, tables, graphs, and more recently, the use of GIS software. GIS facilitates the work of calculation and statistics, as it includes calculation tools within the platform itself, enabling automatic visualization of results in the form of maps and tables. For this reason, we chose a mixed methodology for the study of resilience, where the current state is represented by georeferenced maps that are statistically processed. Social vulnerability, in turn, was calculated using a series of quantitative indicators, statistically calculated and represented in GIS format. This methodology follows the guidelines from the studies of Frigerio et al. (2016, 2019) and R3C - Georesilience.

The choice of indicators

The study based on literature review resulted in the adoption of a vulnerability assessment system based on the Frigerio et al. (2016) method, using GIS technology. The study was based on open data made available by the national government and local administrations. The choice of study area was the extended area of the Cratere of Central Italy, an internal area severely affected by the impact of the 2016-17 seismic sequence. The area involves 138 municipalities in the regions of Lazio, Abruzzo, Marche and Umbria.

The indicators were chosen using the list of indicators mentioned in the previous chapter, created from a review of the scientific literature, which was then re-evaluated from two points of view: 1) availability of open data that can be georeferenced, and 2) execution time (feasible within the timeframe set for the doctoral course). Below is a table of the indicators used:

Indicators	Variables	Vulnerability Impact	Formula
Age	Rate of children (less then five years of age)	Increases	Percentage ratio between resident population aged between zero and four years and total resident population
	Rate of elderly (more than 65 years of age)	Increases	Percentage ratio between resident population aged 65 or more years and total resident population.
	Old age dependency ratio	Increases	Percentage ratio between resident population aged 65 or more years and resident population aged between 15 and 64 years.
	Old age index	Increases	Percentage ratio between resident population aged 65 or more years and resident population aged between zero and 14 years.
Education	High education index	Decreases	Percentage ratio between resident population with a high-school diploma or university degree and total resident population.
	Low education index	Increases	Percentage ratio between resident population with a primary-school certificate and total resident population.
Population density	Population density	Increases	Percentage ratio between resident population and surface area (square kilometres) of the census area.
Quality of housing	Number of occupied historic buildings	Increases	Percentage ratio between occupied dwellings built before 1980 and total occupied dwellings.
	Residential buildings in a poor or state of preservation	Increases	Percentage ratio between occupied residential buildings in a poor state of preservation and total occupied residential buildings.
	Residential buildings in a good or excellent state of preservation	Decreases	Percentage ratio between occupied residential buildings in a good or excellent state of preservation and total occupied residential buildings
Accessibility	National road density	Decreases	Ratio between national road length (miles) and surface area (square kilometres) of the census area, multiplied by four.
	Regional road density	Decreases	Ratio between regional road length (miles) and surface area (square kilometres) of the census area, multiplied by three.
	Provincial road density	Decreases	Ratio between provincial road length (miles) and surface area (square kilometres) of the census area, multiplied by two.
	Local road density	Decreases	Ratio between local road length (miles) and surface area (square kilometres) of the census area.
	Railway density	Decreases	Ratio between railway length (miles) and surface area (square kilometres) of the census area.
Resident foreigners	Resident foreigner density	Increases	Per thousand ratio between resident foreigners and Italian residents.

Tabel 2: Vulnerability Indicators Used in the Case Study. Source: Author.

Data from the 2011 ISTAT census was used because it is definitive and complete. This considerably affects the result, since it takes into account pre-earthquake vulnerability. The ISTAT data was prepared according to the formulas above, establishing percentage ratios for each indicator. The result was normalized by calculating the z score and transformed into georeferenced data using ArcGis software. A new normalization of the values was made to assign values between 0 and 1, in order to enable comparison between different data and the algebraic sum of different maps. Each variable map was summed algebraically to create the indicator map. The algebraic sum does not assign weights to the values of the variables. The resulting map of each indicator was summed algebraically, resulting in the map of the social vulnerability of the Cratere of Central Italy.

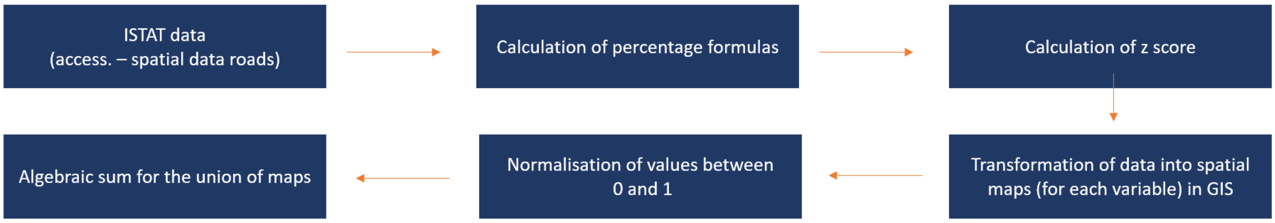

Figure 35: Methodology used for the creation of vulnerability maps. Source: Author.

There is a consensus on social vulnerability factors ranging from lack of access to resources, to the stock and age of buildings, the presence of frail and physically limited individuals and the density of infrastructure and lifelines (Blaikie et al., 2014; Jacobs, Smith, & Goddard, 2004; Frazier, Thompson, & Dezzani, 2014). Some authors also include social capital in terms of social networks and connections that can determine a different degree of resilience to hazards.

The choice of indicators that influence social vulnerability represents the first critical point of the study, as it depends on the quality of the variables available and the subjectivity of their selection. Six indicators were selected: age, employment, education, urbanization, quality of home and ethnicity. Of these, 15 substitute variables explain the positive or negative factors that increase or decrease social vulnerability.

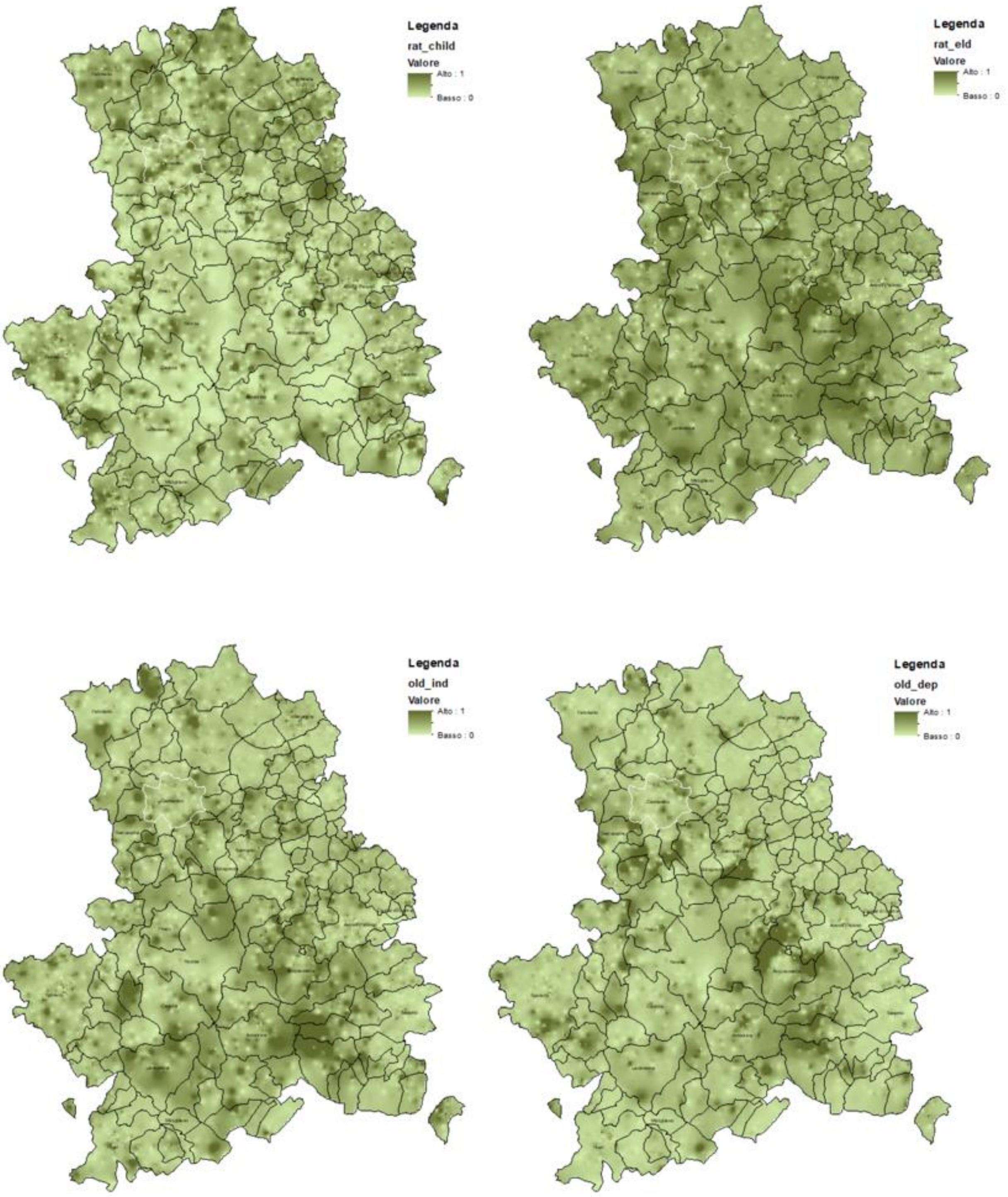

Figure 36: Vulnerability maps of the indicator's representative variables: AGE. Source: Author

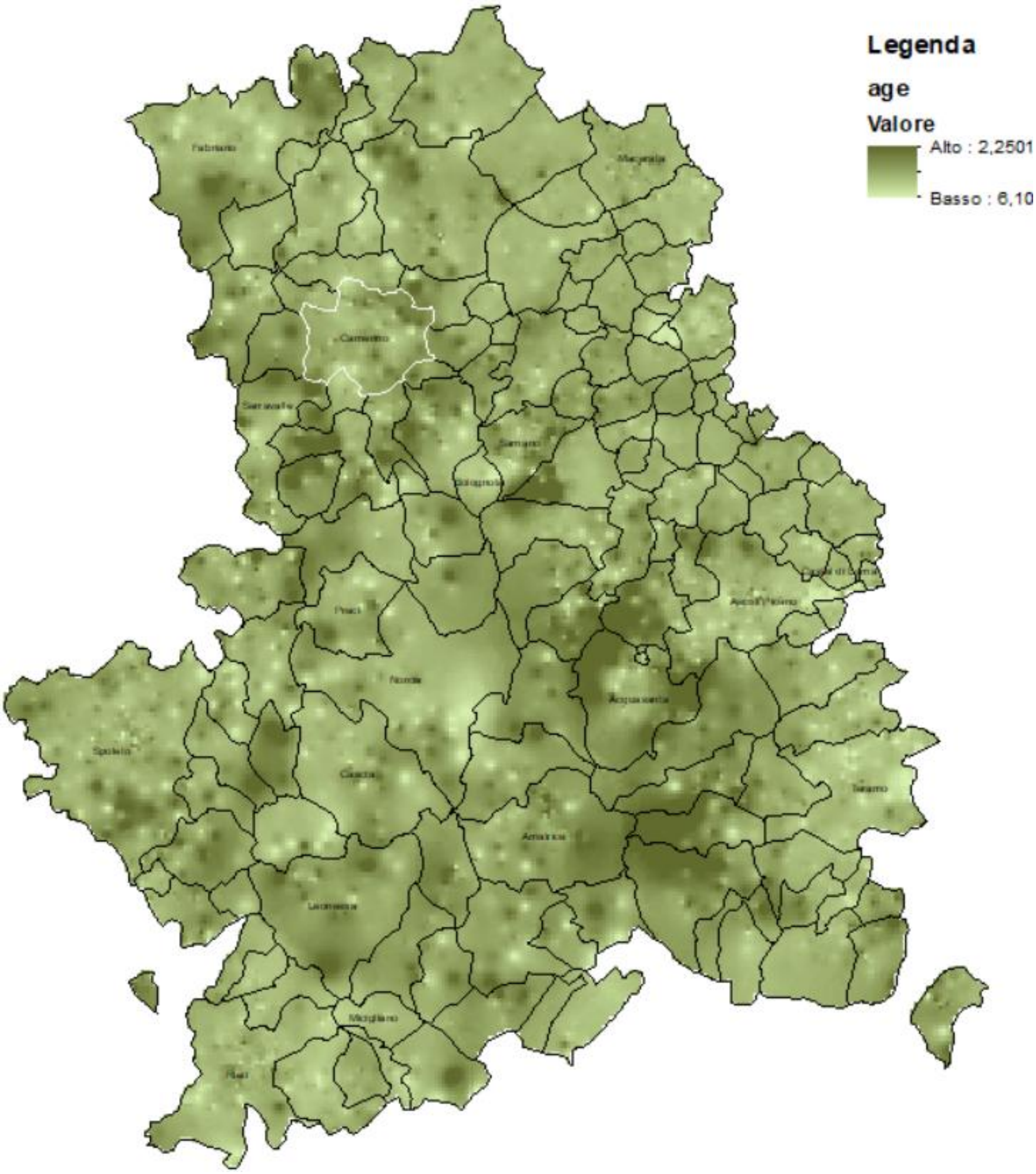

Figure 37: Final sum of the AGE indicator. Source: Author.

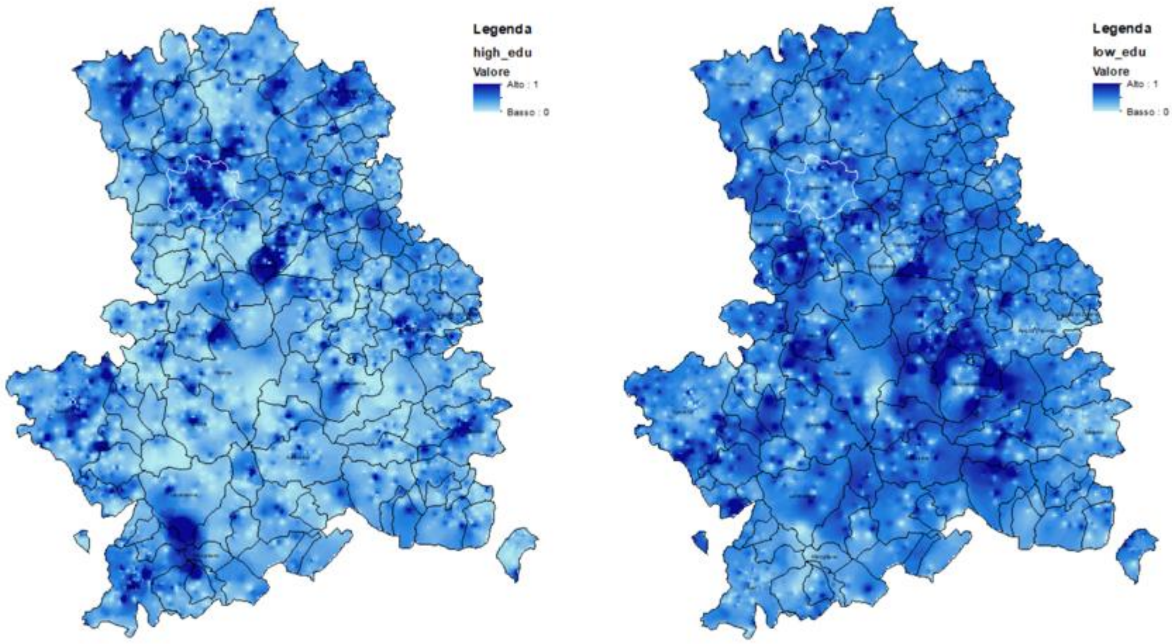

Figure 38: High Education Index and Low Education Index. Source: Author.

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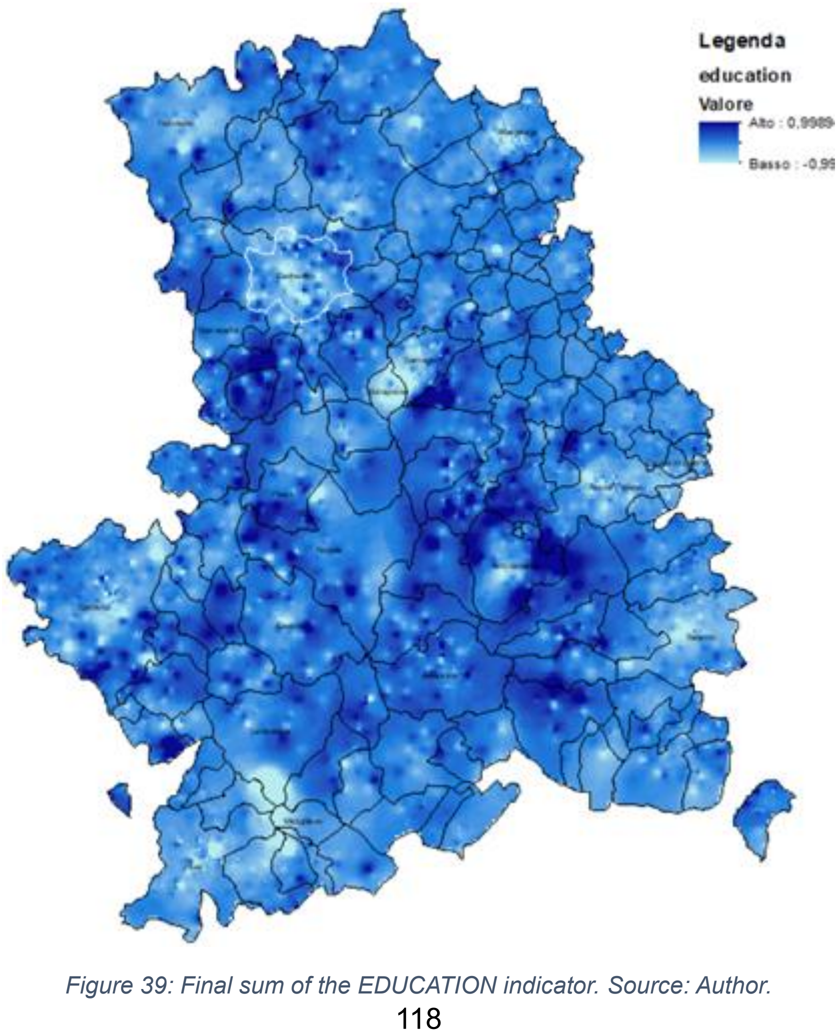

Figure 39: Final sum of the EDUCATION indicator. Source: Author.

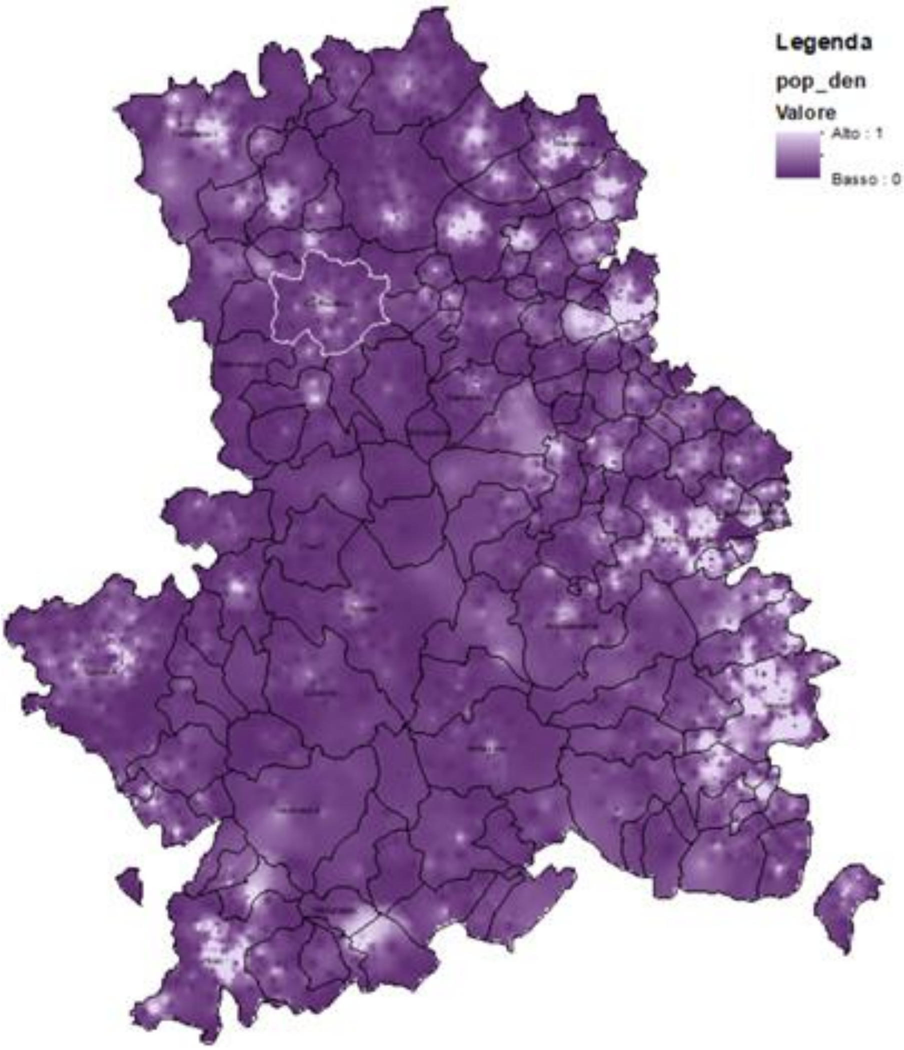

Figure 40: Final sum of the POPULATION DENSITY indicator. Source: Author.

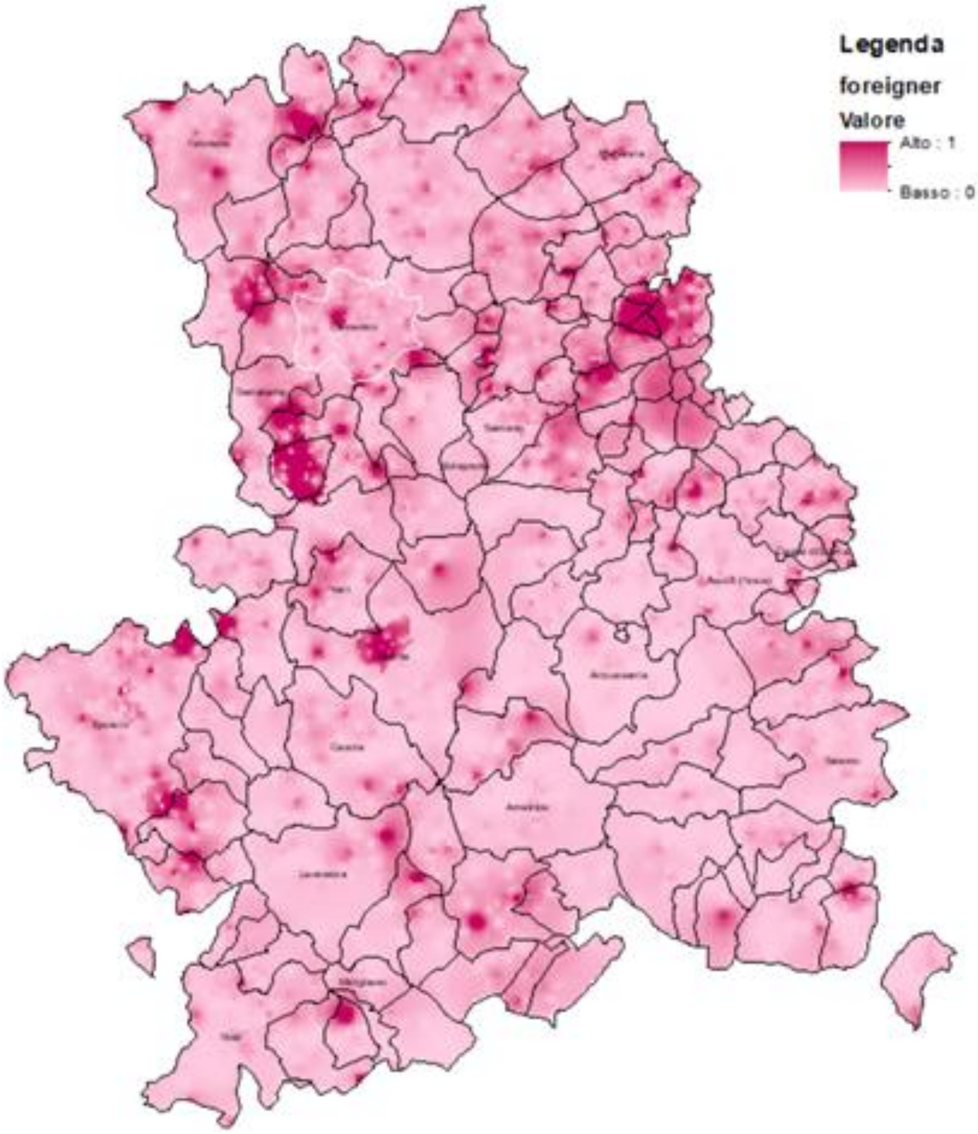

Figure 41: Final sum of the FOREIGNERS indicator. Source: Author.

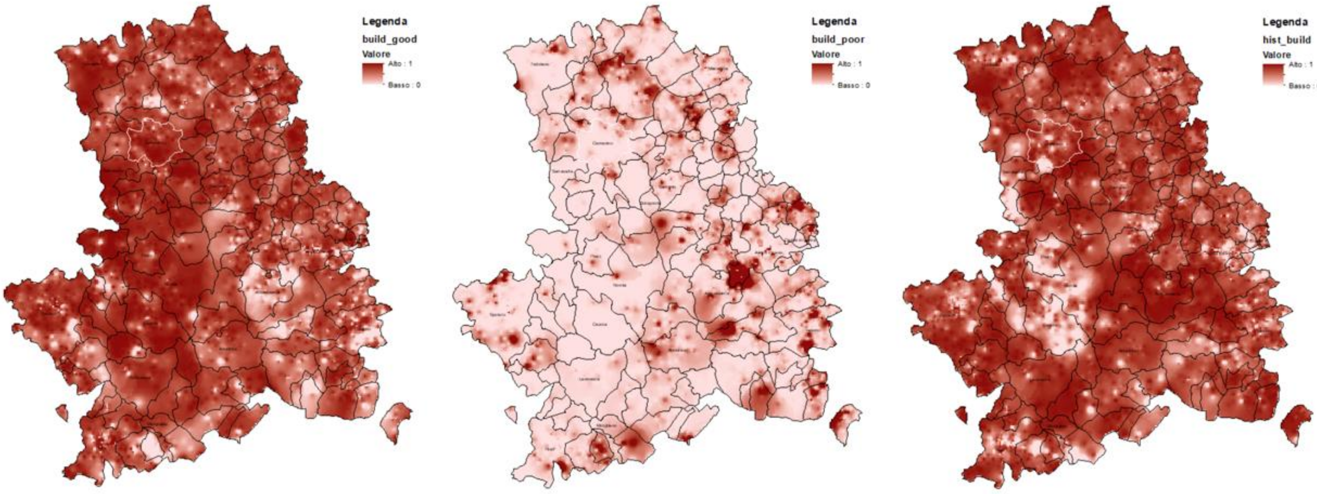

Figure 42: Building quality variables: rate of well-built buildings, poorly-built buildings and rate of historic buildings.

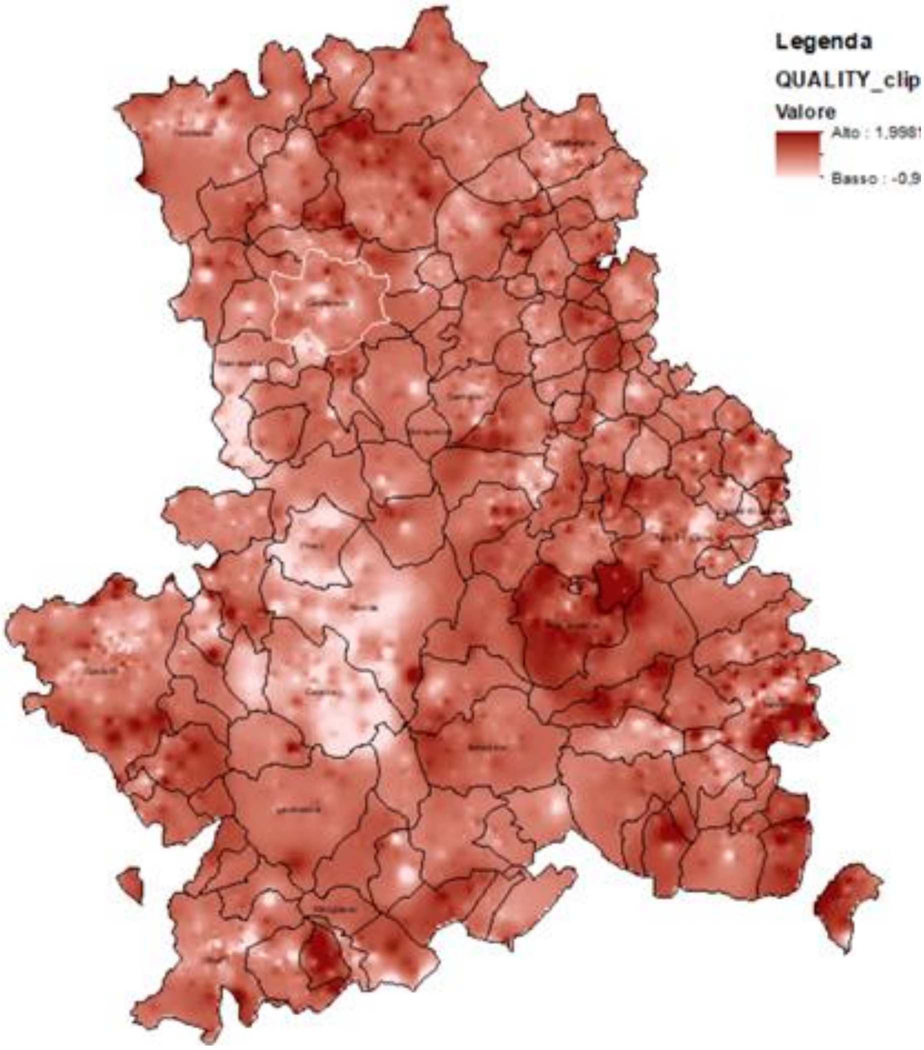

Figure 43: Final sum of the QUALITY OF CONSTRUCTION indicator. Source: Author.

The relationship between vulnerability and topography

In general, it is observed that social vulnerability in the inner areas of Italy is deeply linked to the terrain morphology and historical processes of political marginalization. The mountainous regions, further inland, not only face a higher likelihood of natural disasters, such as earthquakes and landslides, but also bear the weight of decades of political and economic isolation, which worsens their vulnerability conditions.

The age indicator reveals a significant trend of population aging, particularly in the more internal areas at the border of Abruzzo and Marche. This aging is accompanied by an alarming structural dependency index, indicating increasing pressure on the workforce and an imbalance between age groups, which compromises the sustainability of these communities. This area also shows high educational vulnerability, reflected in the low level of qualification within the local population. However, there are some positive spots: cities like Macerata, Camerino, Ascoli Piceno, Bolognola, Teramo, and Micigliano display lower educational vulnerability, with the presence of universities and significant research centers. These areas function as poles of attraction for professional qualification, but they are surrounded by regions with high educational vulnerability, suggesting that many young people from these areas migrate to other places to study and, often, do not return, resulting in a continuous cycle of loss of human capital.

The housing density map shows a clear trend of population densification towards coastal areas, reflecting the migration from the mountains to locations that are more accessible and better served by essential services. This movement towards the coast highlights the regional inequality in the distribution of resources and the search for economic opportunities and better living conditions.

The foreigners' presence map indicates a low rate of foreign residents in most areas, particularly in the higher zones where isolation and lack of infrastructure limit the attractiveness for immigrants. However, there are three areas with higher foreign presence: Norcia, Monte Cavallo - Pieve, and San Ginesio, suggesting the existence of integration hubs or economic activities that attract immigrants to these locations. These centers can be seen as resilience points within the broader region.

Housing quality also appears uneven. The area that includes the internal border between Abruzzo and Marche stands out for its low housing quality, indicating deterioration of physical capital and progressive abandonment of urban infrastructure and services. In contrast, the areas of Norcia, Cascia, and Preci show higher housing quality, particularly when compared to other parts of the region. This may reflect a process of recovery or more recent investments in local infrastructure. This scenario points to an interdependence between social vulnerabilities, with factors such as quality of life and access to essential services directly connected to the state of physical infrastructure and the local demographic dynamics.

In summary, the vulnerabilities of these areas are multiple and interconnected, involving social, economic, educational, and infrastructural aspects, which make recovery and revitalization a complex and multidimensional challenge. Studying these vulnerabilities is crucial for developing sustainable development and resilience strategies that consider local specificities and seek to integrate the inner areas into the national economy in a more inclusive and equitable manner.

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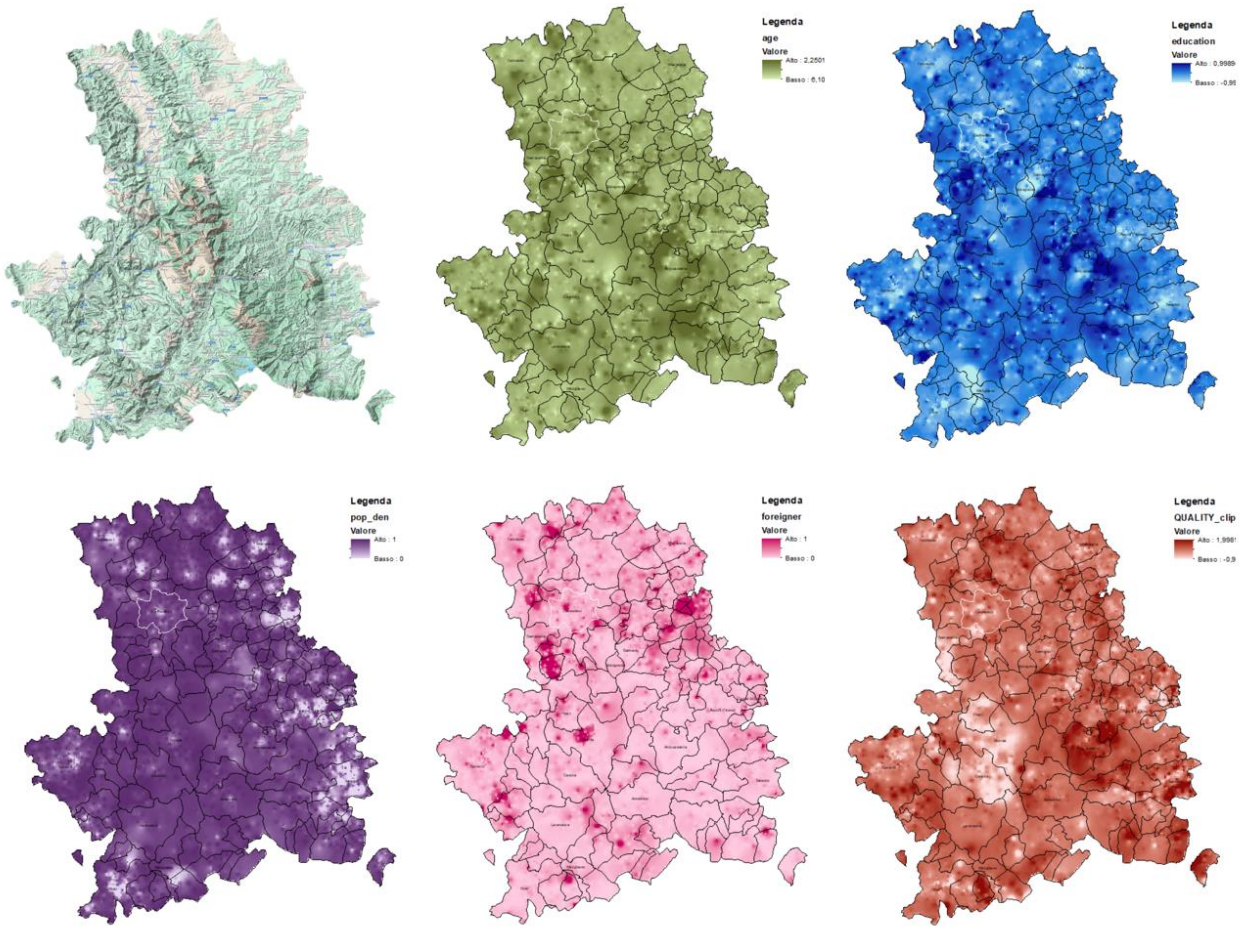


Figure 44: The relationship between vulnerability and topography. Source: author.

Part 04: Application of the tool in the case study: Camerino (MC)

4.1 Getting to know the study area: the city of Camerino

4.1.1 Characterization of the study area

Camerino is a municipality in the Province of Macerata, in the Marche. Situated between the valleys of the Chienti and Potenza rivers, it sits on a ridge in the center of the mountainous area enclosed to the south by the Monti Sibilini and to the north by Monte San Vicino, at an altitude of 661m. The territory is characterized by a hilly landscape, with alternating cultivated fields, small woods and centuries-old quecias. The city has just over 6000 inhabitants, most of them brought by the presence of the University of Camerino, which has been a notable presence since medieval times. It has an area of 129.88 km² and a density of 46.57 ab./km².

Figure 45:View of the upper town of Camerino. Source: Author

4.1.2 Vulnerability

The demographic trend

The presence of the University of Camerino since 1336 has been an important factor in the city's development. The city's attractiveness as a place of study can be seen above all in the demographic trends compared to neighboring cities. There is a significant number of young people living in the city compared to other municipalities, but even so, the largest population group is between 55 and 75 years old, confirming the ageing trend of the region's population.

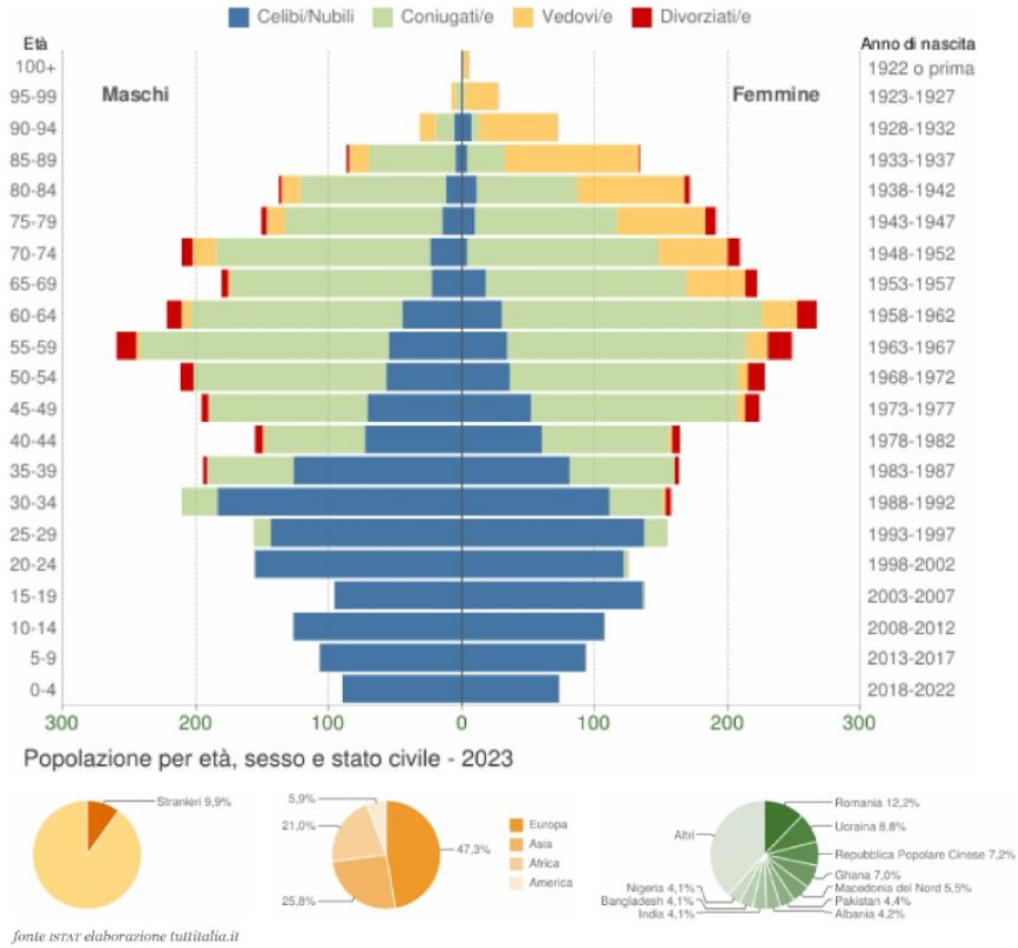


Figure 46: Census of the population of Camerino. Source: https://www.tuttitalia.it/marche/79-camerino/statistiche/censimenti-popolazione/

The university's attractiveness is further demonstrated by the remarkable number of foreign residents, almost 10% of the population in 2023. It should be borne in mind that this migration continues on a negative trend, following the depopulation curve that the city has been experiencing since the 1920s. It is important to note that this negative trend was quite slow until after the Second World War. In the 1950s there was the first significant drop and this rapid depopulation has been following the same course.

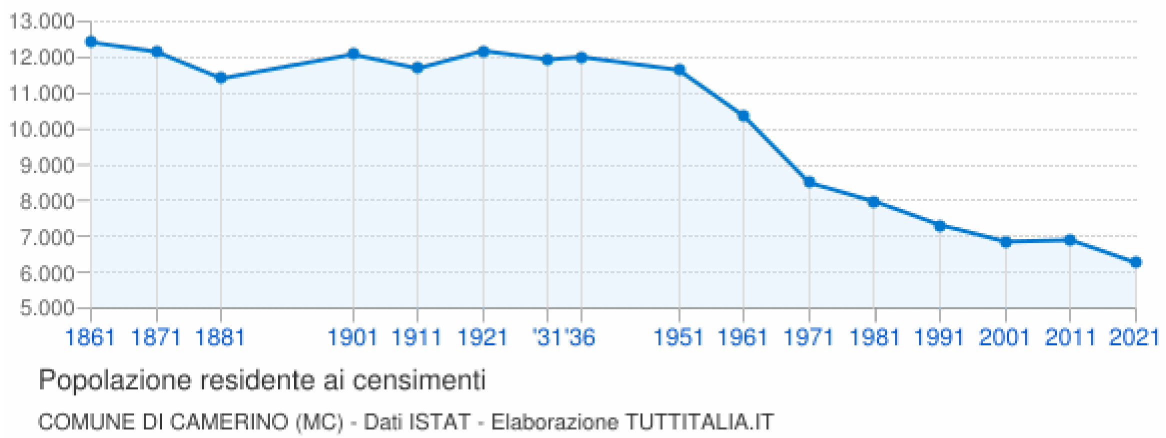


Figure 47: Camerino Demographic Trend. Source: https://www.tuttitalia.it/marche/79-camerino/statistiche/censimenti-popolazione/

In relation to the percentage change in population in the province of Macerata and in the region as a whole, we can see that Camerino has been losing population drastically since the 1960s and especially in the 1970s, while the province and the region showed positive trends until 2020, falling considerably with the advent of the pandemic.

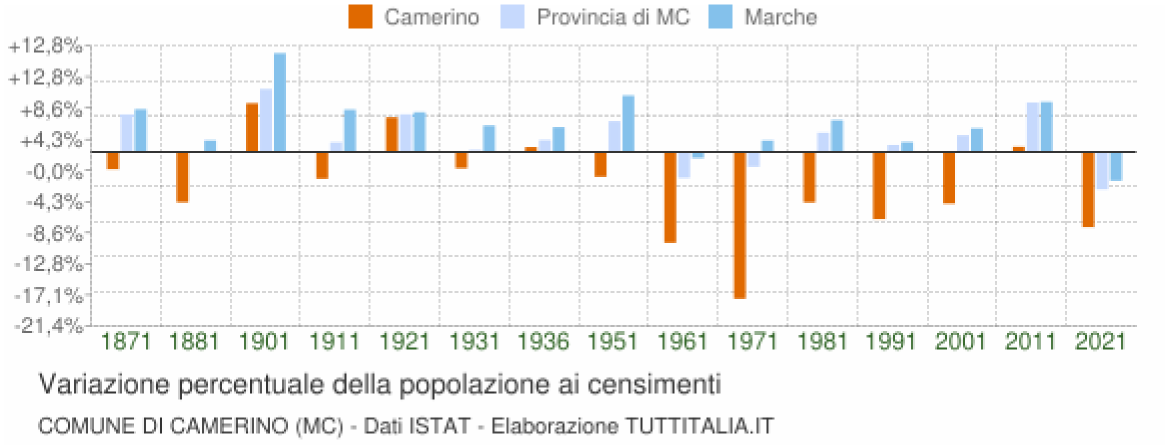


Figure 48: Percentage of the population in the censuses. Source: https://www.tuttitalia.it/marche/79-camerino/statistiche/popolazione-andamento-demografico/

With regard to the pandemic period, it was the period in which Camerino lost the most residents in the last 20 years, surpassing the rates of the 2011 and 2016 earthquakes (when the resident population remained practically stable).

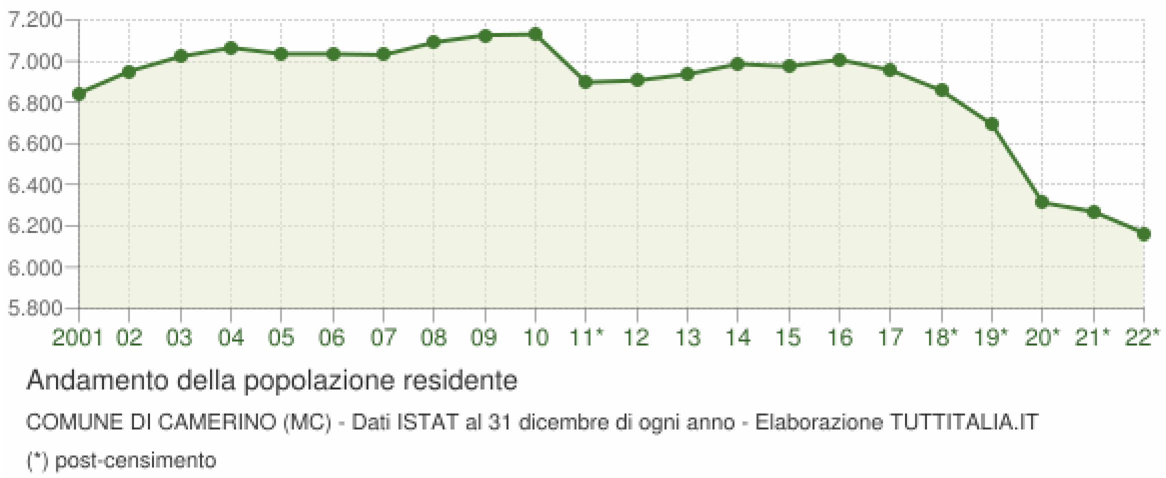


Figure 49: Resident population growth. Source: https://www.tuttitalia.it/marche/79-camerino/statistiche/popolazione-andamento-demografico/

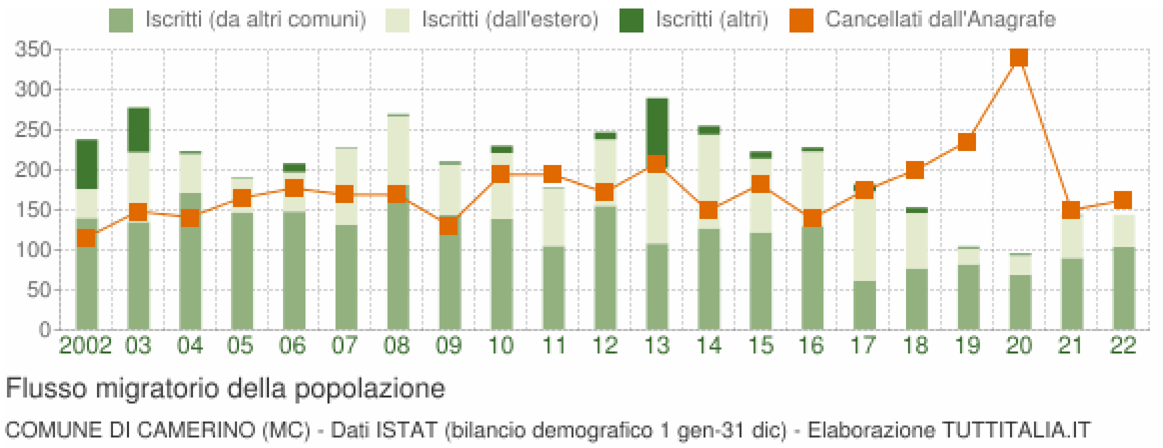


Figure 50: Migratory flow of Camerino's population

Environmental, social and economic vulnerabilities

From an environmental point of view, the city is located in a highly active seismic region, which makes it particularly susceptible to earthquakes, as demonstrated by the devastating event in 2016, when Camerino was the second most affected city, behind Amatrice. Despite progress in reconstruction, Camerino continues to be exposed to recurrent seismic risks and also faces challenges related to hydrogeological vulnerability, with areas prone to landslides and flooding, aggravated by extreme weather phenomena. These factors require continuous monitoring and the implementation of effective prevention and adaptation measures in order to guarantee the safety of the population and the environmental sustainability of the city.

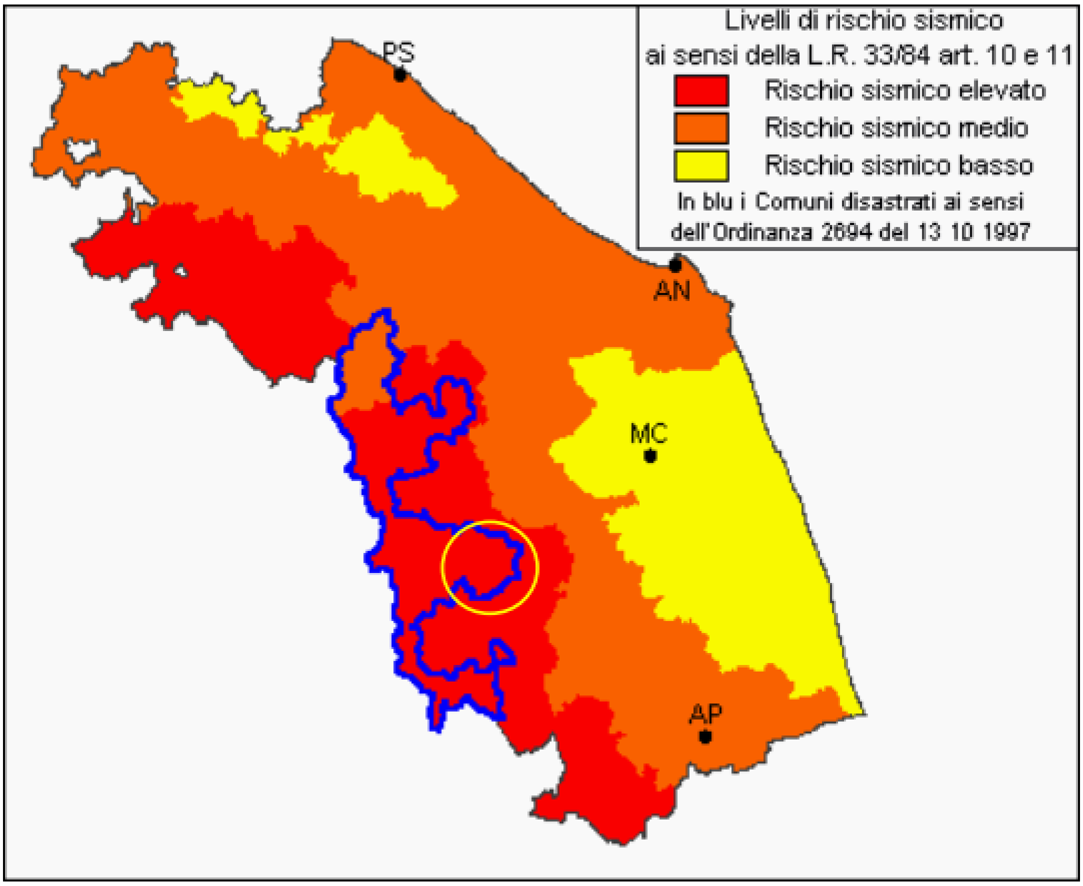


Figure 51: Camerino's position in relation to the seismic risk zones. Source: Microzonazione Regione Marche

In the social sphere, the city is facing a process of accelerated population aging, which overloads public services, especially health services, and increases the demand for care for the elderly. This phenomenon also contributes to the emptying out of urban areas and the decrease in the active workforce, as many young people migrate in search of better educational and professional opportunities in large urban centers. In addition, the shortage of affordable housing is a significant obstacle to the reintegration of the population affected by disasters. Reconstruction, although progressing, still lacks an adequate supply of housing, which hinders the full return of residents and compromises the revitalization of the affected areas.

Prior to the 2016 seismic sequence, the city of Camerino had a remarkably rich network of cultural and social associations - many of them affiliated with the university, alpine clubs, and the broader cultural landscape of the region. Approximately 80 associations were active in the municipality, most of which were headquartered in the historic center. This area, severely affected by the earthquake, was declared a red zone within the first 24 hours of the emergency and has remained largely inaccessible and unused to this day. As many community leaders and association members had their homes damaged and their meeting spaces rendered unusable, they were relocated to emergency shelters and hotels dispersed across the surrounding territory. This geographical dispersion, combined with the loss of physical spaces for social interaction, significantly weakened the organizational capacity of the associations and their ability to respond effectively during the emergency phase.

Some of the associations and *comitati* currently active in the area were established after the earthquake, such as *Iononcrollo Odv*, one of the most engaged organizations in civic participation and social activism in the post-seismic context. In September 2024, the association inaugurated the

Quartiere delle Associazioni, a space consisting of two structures of 150 square meters each, which will host a multifunctional center and various local initiatives, thus filling the gap left by the many associations that lost their headquarters. Additionally, other associations and professionals launched initiatives focused on community engagement, cultural promotion, and reconnecting with the local population, aiming to better understand the needs and aspirations that emerged in the aftermath of the disaster.

In 2017, the Municipality of Camerino and the Commissioner for Reconstruction, in collaboration with Mario Cucinella Architects and the School of Sustainability, coordinated the participatory process *Workshop Ricostruzione Camerino*, which resulted in the creation of a strategic planning document for the city's reconstruction. The central idea was that reconstruction should be seen as an opportunity for renewal, development, and growth—a chance to rebuild "better than before" rather than simply returning to the status quo. This strategy is also grounded in the need to engage citizens in a concrete and meaningful way, inviting them to actively participate in a true co-design process that redefines the city's future. In parallel, several projects developed within the University of Camerino contributed to the collective effort to explore potential strategies for the city's rebirth, addressing social, economic, and physical resilience from diverse interdisciplinary perspectives. Among the most significant outcomes are:

Demolitions and Alternative Solutions

The demolition of certain structures—such as the former courthouse, the *Casa del Fascio* (excluding the tower), and buildings in the San Filippo area—is proposed to create new open spaces, enhance views toward the landscape, and improve urban permeability. The rationalization of built volumes is seen as a strategy for structural consolidation through a reduction of building mass. Adaptive reuse is suggested for several key sites, such as converting the *Caserma dei Carabinieri* into a museum hub and transforming the former *licei* area into underground parking. The area surrounding *Santa Maria in Via* is subject to various proposals, including partial preservation, ruin-as-memorial interventions, or protected walkways for cultural access. Revitalizing the city also involves reintroducing community-centered functions, including cinemas, associations, and incubators.

City Walls and Accessibility

The redesign of pathways along the city walls is proposed in collaboration with local organizations such as the Alpine Club and CUS Camerino. Suggested interventions include underground routes, evacuation paths, and enhanced permeability between the walled city and its surroundings. Nighttime lighting of rest areas and walkways is also recommended. Clear distinctions must be made between pedestrian and vehicular accessibility. The enhancement of strategic nodes—such as the *Pincetto* and the *Orto Botanico*—through improved visibility and reprogramming of adjacent buildings is considered key to restoring spatial continuity.

Mobility and Circulation

Urban mobility should be rethought with a focus on the needs of students and elderly residents, prioritizing sustainable modes of transport such as electric vehicles, bicycle lanes, and pedestrian paths. Proposals include underground parking (e.g., beneath the former *licei*), and the relocation of camper areas to the countryside to preserve the landscape. Greater integration between the historic center and newer developments is essential, including the potential revival of the former tram route between Camerino and Castelraimondo. Existing but underutilized infrastructure must be upgraded and reactivated.

Camerino as a Living City

Reversing the trend of depopulation—which predates the earthquake—is a central objective. It is essential to identify the number of residents willing to return to the historic center, to re-establish the economic value of central housing, and to foster local entrepreneurship. The absence of a multifunctional center for conferences, performances, and university events is a major gap. Resources should be networked, ideally through local associations, which urgently require dedicated operational spaces. Ordinances must be coherent and clearly communicated to avoid confusion and contradiction.

Economic, Cultural, and Social Resources

Camerino's cultural, gastronomic, historical, and artisanal heritage must be strategically leveraged for tourism development. Proposals include the establishment of a museum hub, the enhancement of the *Orto Botanico*, and a dedicated *Casa delle Associazioni*. Investment in traditional crafts—such as paper-making and silk dyeing—is recommended, alongside promotion of theater and events such as open rehearsals (*circuito zero*). The city must also improve communication of cultural programming to external audiences.

The Territory and Camerino's Relation to Surrounding Hamlets

Camerino's rural hamlets have experienced ongoing depopulation since the 1950s, worsened by the recent earthquake. Yet the territory holds significant ecological and cultural value, including cycling paths, historic trails, and natural landscapes. Developing short- and long-range itineraries could foster deeper engagement with the surrounding area. Urban expansion toward Castelraimondo is viewed as an opportunity for territorial integration—particularly through the redevelopment of areas like *Cortine* and *Torre del Parco*—and the functional activation of vacant areas that do not require central placement. While the new university campus is being developed in Castelraimondo, preserving the characteristic coexistence of students and residents in Camerino's historic center remains a key challenge.

Nevertheless, the residents encountered during the field visit—particularly in the university area and near the newly constructed commercial center, given that the historic center remains uninhabited—as well as comments left on the municipality's social media platforms, expressed a strong connection to Camerino's cultural identity and a deep sense of loss regarding the prolonged closure of the historic center. Above all, they voiced growing frustration over the extensive delays in the reconstruction process. Nearly a decade after the earthquake, no reconstruction work has been initiated. It was only at the end of the previous year that the intervention area was officially delineated, along with the presentation of a preliminary plan for the reconstruction of the historic center. However, to date, no construction sites have been activated, and only emergency stabilization work has been carried out on some of the damaged buildings.

Economically, Camerino suffers from the destruction of its commercial infrastructure, which was heavily impacted by the earthquakes, and from its dependence on tourism as one of its main sources of income, making the city vulnerable to events that compromise its attractiveness. The city also faces challenges in the agricultural sector, which is fundamental to the local economy, since climate change and the migration of young people from the countryside to the cities jeopardize the continuity of rural activities. The lack of economic diversification intensifies this vulnerability, making the city more susceptible to sectoral crises. It is therefore urgent to adopt public policies that promote more diversified, sustainable and resilient economic development, capable of mitigating the impacts of environmental and social vulnerabilities and guaranteeing Camerino's recovery and growth in the long term.

In some cases, the consequences of the earthquake were the occasion for positive interventions for the future of the urban center, as in the case of the former prison, the courthouse area and the school complex near Rocca.

4.1.3 Current government programs and plans

Programma Straordinario di Ricostruzione di Camerino – PSR

The PSR of Camerino, approved by Decree No. 3 of 26/04/2022, aims to provide a safe, orderly and rationally rapid reconstruction, respectful of the historical-architectural, cultural-identity and landscape-environmental characteristics. The *Programma Straordinario di Ricostruzione* (PSR) of Camerino was developed to guide the recovery of the city's historic center and surrounding areas, which were affected by the earthquakes that occurred since 2016. The main objective of the PSR is to ensure a safe reconstruction that respects the historical, cultural, and environmental characteristics of the city, while also promoting a rapid and effective recovery of urban life. The PSR takes into account the medieval layout of the city, with narrow streets and a complex network of public and private spaces that need to be rebuilt in a coordinated manner, without compromising safety and livability for residents.

Camerino's reconstruction is divided into two main strategies: one for the short term, focused on the immediate rebuilding of essential infrastructure, and one for the long term, which addresses issues of urban regeneration and public space revitalization, with an emphasis on preserving the city’s historical identity. The PSR includes the demolition of damaged buildings, the reconstruction of important public structures such as the Palazzo Ducale and Teatro Comunale, and the creation of new escape routes to ensure the safety of the population in case of future disasters. Additionally, areas that require specific interventions have been identified, such as the demolition of the old Scuola Betti building and the construction of a new access road to the Pincetto area, which will improve connectivity with the historic center.

To ensure the quality and safety of the reconstruction, the PSR adopts guidelines that must be followed during the restoration of historical buildings. Restoration projects must comply with seismic safety standards while preserving the architectural and cultural characteristics of the city, using traditional materials and, when necessary, innovative technological solutions. The implementation of the PSR also takes into account the need to simplify bureaucratic processes and accelerate works so that reconstructions can be carried out more efficiently and without excessive legal obstacles.

However, the PSR also considers the need for broader strategic planning for the social and economic regeneration of the city, including the revitalization of public services, recovery of local businesses, and support for cultural initiatives. To this end, the worksite organization (*cantierizzazione*) plan was structured based on criteria of accessibility and safety and includes the use of advanced technologies such as laser-scanning to create SIT that will aid in managing the reconstruction. Financial support measures have been established to facilitate the work, including incentives for the early completion of projects.

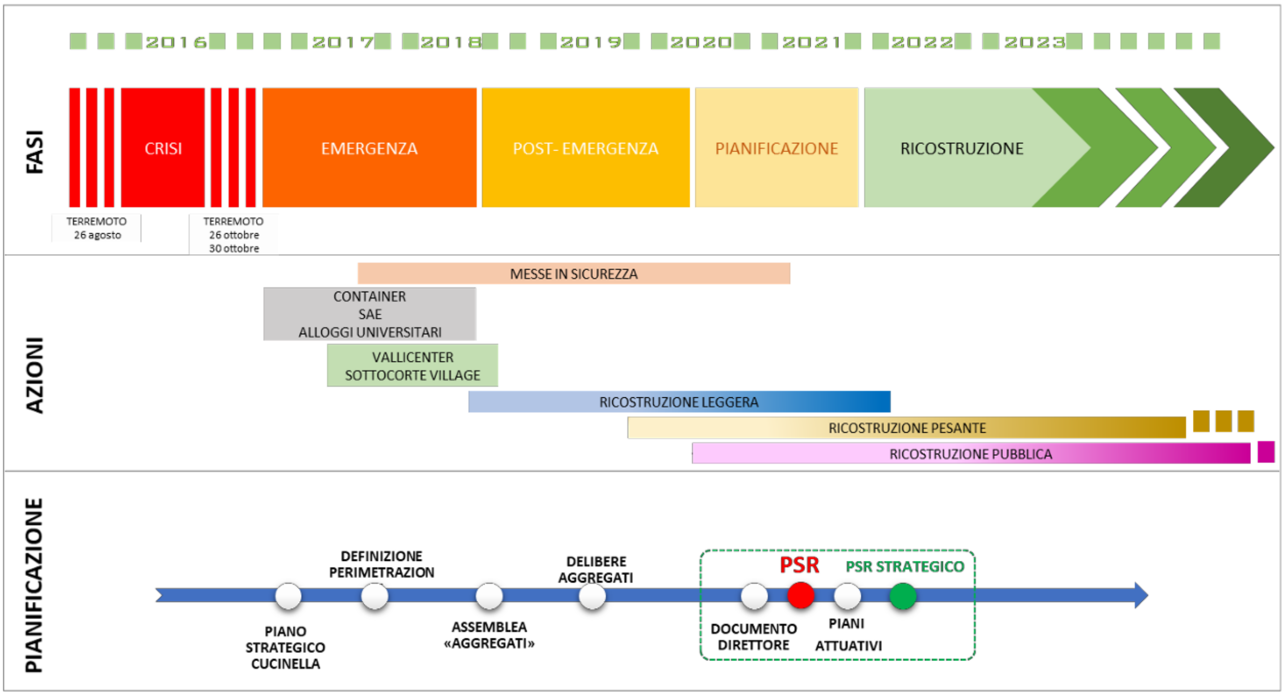


Figure 52: Phases of Camerino's PSR.

4.2 Defining the study systems

The definition of the systems covered in this study is the result of research based on previous Geodesing research (Campagna et al., 2016) and the analysis of the vulnerabilities and attractions of the area carried out by two studies in particular. The first (Pierantoni et al., 2022), covers the entire study area (Crater) and after an exhaustive analysis of the characteristics of the territories and communities, identifies 9 pathways for a sustainable post-earthquake revitalization strategy:

1. Safe, Inclusive and Sustainable Cities and Villages.
2. New service system between proximity and polycentrism
3. Networked territories: digital connections and mobility
4. The value of diversity: natural, cultural and landscape heritage
5. Innovative supply chains in agriculture, forestry and animal husbandry
6. Tourism and services toward an evolved tertiary sector
7. Local manufacturing and creativity in a green economy
8. Training, research and better dissemination of knowledge
9. Permanent forum with communities

The second study (Pierantoni et al., 2019), specific to the Marchigiana crater area, identifies the vocation of 11 development paths:

1. Better living here: for renewed attractiveness of Apennine villages
2. Borghi in rete: Connectivity and sustainable mobility
3. Museums for the territory I: The museum and scattered cultural heritage system
4. Museums for the territory II: The museum and scattered cultural heritage system - support for operating activities
5. Innovating to conserve: Pilot reconstruction projects of architectural heritage in its productive and landscape context
6. Creativity and Made in Italy: Toward economic development with a cultural matrix
7. The green capital of the Apennines: renewable energy and resources

8. The plant heritage: Toward an enhancement of plant products for more profitable, integrated and eco-sustainable farms
9. From pasture to table: The profitability of the local livestock supply chain, between differentiation and diversification
10. Rebuilding better: Research and training pathways for innovation and development
11. Open data and monitoring the reconstruction process

The synthesis of these studies thus reveals a comprehensive characterization of the region, the vulnerabilities it faces, and the opportunities to exploit its potential, especially in terms of environmental and ecological potential, environmental, cultural and historical heritage, and traditional practices. Research, training and innovation play a crucial role in all proposals, particularly in building the capacity of governments and communities to deal with the possibility of new natural or man-made disasters. In this context, the assessment systems designed to analyze resilience to natural disasters in the Crater region in central Italy following the 2016 earthquake are segmented into four systems outlining the territory's vulnerabilities and six systems highlighting its potential, as described below:

EVALUATION SYSTEMS
01 Green infrastructure
02 Water system
03 Agriculture
04 Transportation
05 Energia
06 Settlements (Housing)
07 Tourism
08 SMART
09 Trade/ Crafts/ Industry
10 Cultural Heritage

4.2 Communication and target

4.2.1 Communication and participants

The target for the application of the methodology was defined as postgraduate students (second level Master's and PhD) from various areas linked to urban design such as architecture, town planning, geology, geography and social sciences, university and municipal technicians and other interested parties. Communication was made via an email sent by Professor Massimo Sargolini.

Characteristics two participants

A total of 24 people took part (2 of whom didn't answer the questionnaire and one of whom refrained from creating a profile on the GeodesignHub platform, even though he participated in the projects and discussions through his colleagues). The multidisciplinarity of the group was guaranteed in 9 different areas of work, with a greater participation of urban planners (27.3%), followed by architects and geologists (both with 22.7%) and social scientists (9.1%). The other disciplines had a lower percentage but were no less important and were characterised by the following areas: Engineering, Geography, Botany and Biology, as well as Public Administration.

The majority of participants are academics, a fact triggered by the greater flexibility of students to have two full days at their disposal. Half of the participants are studying for a doctorate, around 27.3% are employees, officials or technicians at universities or city halls, 13.6% are university researchers and only 9.1% are self-employed professionals. The participants are part of various institutions that are important to the wider field of study. The vast majority are linked to universities or research centers such as Unicam, the University of Aquila and GSSI. Two participants are part of local administrations, one from the town hall of Camerino and one from the town hall of San Ginesio. Most of the participants (31.8 per cent) live in Camerino. Even among the participants who don't live in Camerino, many say they have a good knowledge of the city.

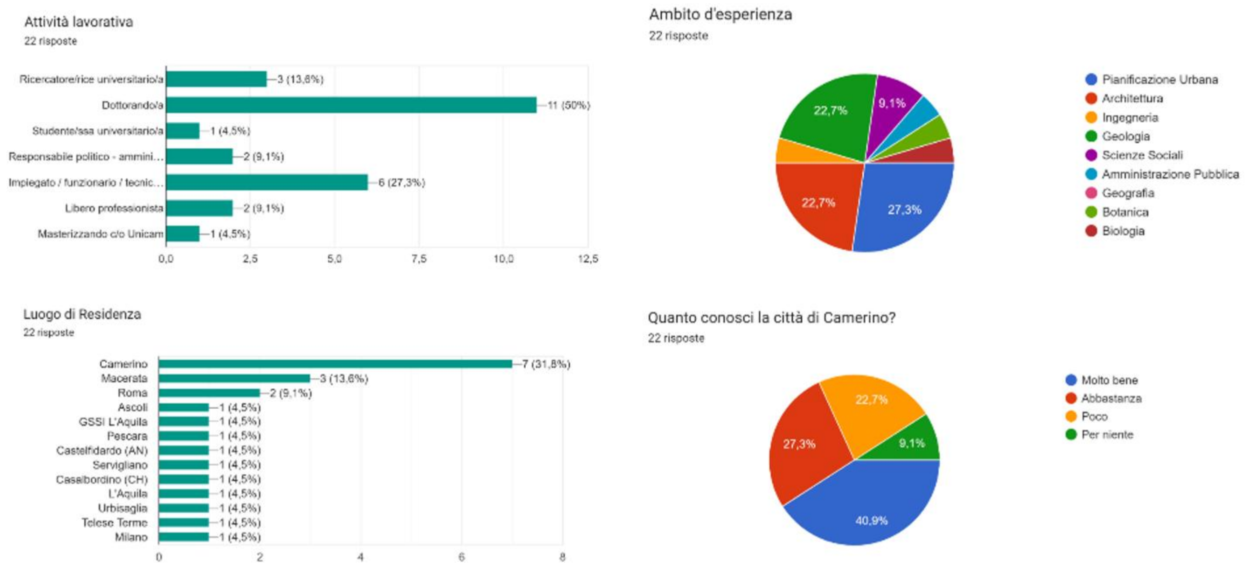


Figure 53: Characterization of workshop participants based on the registration questionnaire. Source: Author

4.3 The Workshop

The Workshop took place on July 22 and 23, 2024, at the Geology Campus of the University of Camerino and was part of the BetterLife BootCamp. On the first day, participants took part in an informative session. They were introduced to the technical material produced, through a link to an ArcGIS StoryMap[4] where they could access all the factual status maps of each system, reports on the decisions made and how the areas were evaluated, as well as copies of the plans made available by the Municipality. This material remained accessible to participants throughout the entire workshop. In addition, there were presentations on the importance of social engagement research, the objectives of the workshop, and the available materials, such as the vulnerability maps. They also took part in a training session on Geodesign, including its theory, framework, and a demonstration of how to use the GeodesignHub platform. The day ended with a technical visit to the historic centre..

4.3.1 The field survey

The Field survey set off from the University of Camerino (Geology Campus) towards the historic centre. The route was guided by researcher Flavio Stimilli, who explained the history of the city, its urban evolution up to the present day, the main problems (geomorphological and hydrogeological

[4] The platform payment was suspended, and the provider ESRI – StoryMap deleted the material from the platform. The maps and administrative documents made available can be found at the following link: https://drive.google.com/drive/folders/1oI3iZm_93WJ4-8m1nILibl9FM70zKSej?usp=drive_link

characteristics with the distinction of the areas most and least at risk of landslides and seismic areas), the effects of the 1997 and 2016-17 earthquakes, new built-up areas, SAE, new slow and fast mobility routes and opportunities for the city and the territory. The tour, outlined in the map below, lasted around 3 hours.

We began our walk through the red zone of the historic centre, passing through the three lanes established for reconstruction. Throughout the walk in the red zone, various questions were raised, debated and clarified, including:

- Earthquake damage: demolitions, reconstruction status
- Changes to the urban fabric: as in the case of the school and the transfer of other services to areas neighbouring the SAEs
- Particular characteristics about cultural heritage: such as the case of the church and the investments for its securing interventions and reconstruction. Uncertainty about the feasibility of reconstruction or the possibility of its total demolition.
- Characteristics of historic buildings
- Curiosities about the reconstruction process (government level).

The participation of people from the area and neighbouring towns and from various disciplines was essential. Many questions were answered in a relaxed manner. Another important factor was the participation of people linked to the public administration, who took an active part in all the phases: pre-shake, emergency and reconstruction. The participation of local residents was active, with relevant considerations about the risks to which the territory is exposed, particularities about the city, its activities and its inhabitants and about the reconstruction process. The participation of local residents with different backgrounds and different work experiences, such as those working in the local and neighbouring town halls and the various technicians and experts, was crucial in describing the territory and dispelling doubts.

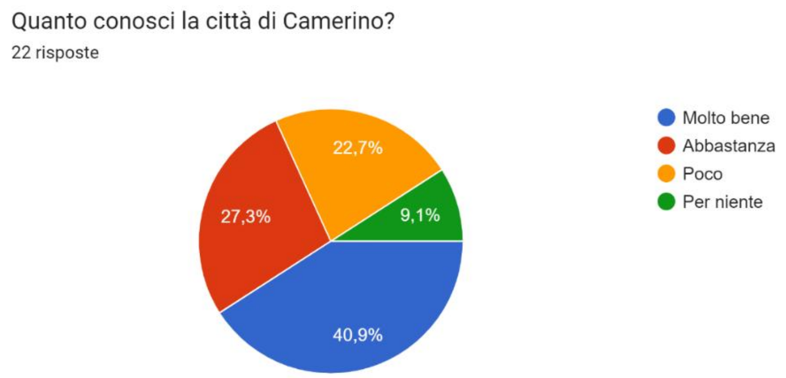


Figure 54: Answers to the questionnaire about how much the participants knew about the city. Source: Author

Figure 55: Field survey of the historic center of Camerino. Source: Author

4.3.2 Sharing data and information

Participants attended an information day:

1. Presentation of the topic and greetings (Prof. Massimo Sargolini)
2. Community engagement in science: The BetterLife project (Ana Sopina, Flavio Stimilli and Valentina Polci)
3. Participatory GIS tools (Prof. Michele Campagna)
4. O Geodesign: Theory and framework (Prof. Michele Campagna)
5. Camerino's disaster resilience (Aline Soares Cortes)
6. Disaster information
7. Research methodology
8. Representation model, Process model and Evaluation model

4.4 The Models

4.4.1 Representation Model

The georeferenced databases for each system could be accessed at:: https://arcg.is/0arHGW0[5]

Cultural Assets

The region has an invaluable artistic heritage, rooted in centuries-old trajectories that have shaped the region's cultural identity. The region has a widely dispersed cultural and historical heritage, made up of small historic villages that are often in a state of semi-abandonment due to population decline and the damage caused by the 2016/2017 earthquake sequence. In addition, there are small museums that face financial challenges in managing and maintaining their collections, many of which are unusable due to seismic damage or insufficient operational standards. The supply of museums is quantitatively high, but qualitatively limited and complex to manage due to the diversity of ownership: public, private and diocesan, and the shortage of qualified professionals for the management and preservation of movable and immovable property.

The historic center is located at a height of over 600m on a rocky hill, running longitudinally along the crinale that separates the Potenza River Valley from the Chienti River Valley, in a NE-SO direction. It is made up of several sites of historical and cultural interest such as:

1. Piazza Cavour
2. Duomo di Santa Maria Annunziata (XIX sec)
3. Palazzo Arcivescovile (XVI sec)
4. Palazzo Ducale (XV sec)
5. Complesso Palazzo Comunale Bongiovanni e Teatro Filippo Marchetti (XIX sec)
6. Piazza Garibaldi
7. Pincetto e Chiesa di San Francesco (XIII sec)
8. Chiesa di San Filippo (XVIII sec) e la piazza Filippo Marchetti (e il tribunale oggi demolito)
9. Polo museale e universitario del Convento di San Domenico
10. Rocca Borgesca (o dei Borgia) (1503)
11. Chiesa di Santa Maria in Via (XVII sec)
12. Piazza e Basilica di San Venanzio
13. Tempio della Santissima Annunziata (XV sec)
14. Monastero di Santa Chiara (XV sec)

The extended territory of the research, the Cratere Maceratese, also has other examples of artistic and historical assets (museums, archaeological sites and architectural assets) scattered throughout the territory. Many of them are partially useless in terms of their functions and unsuitable for the standard of operation.

Cultural assets, as witnesses to history and icons of local culture, have the potential to drive regeneration and territorial development processes. Their reconstruction can be a catalyst for revitalizing the economy and communities. Proposals will be needed to link post-earthquake reconstruction to innovative approaches to the use and management of cultural heritage, primarily with a view to improving the attractiveness of tourism and, consequently, attracting economic and social capital capable of raising service standards. Improving the quality of exhibitions can be achieved through the design and/or application of technologies such as IoT and ICT. Ultra-broadband connectivity can make it easier for tourists to access information and enable virtual access, becoming a key tool for communication and local attractiveness, potentially strengthening self-esteem and the

[5] After the conclusion of the research, the platform payment was suspended, and the provider ESRI – StoryMap deleted the material from the platform. The maps and administrative documents that had been made available can now be found at the following link: https://drive.google.com/drive/folders/1oI3iZm_93WJ4-8m1nILibl9FM70zKSej?usp=drive_link

community's sense of belonging and identity (08). Educational policies are welcome for training new professionals and promoting local heritage in educational institutions.

Examples of good practices can be seen in various categories of museum retreats, formed by public-private partnerships aimed at optimizing museum management, the qualification of professionals and dissemination processes, while also benefiting interconnected sectors such as tourism and hospitality. The increase in the number of tourists can contribute to the redditività of local commerce, especially for small producers and artisans (09). Museums facilitate the exchange of experience and the ongoing training of the professionals involved, as well as incorporating participatory management processes and the involvement of the local community. In this context, the development and re-qualification of these spaces can also serve as a meeting point for local residents outside the opening hours, broadening the range of services offered and promoting the active participation of local people.

A model of shared approach to management, which provides for the reorganization of the functioning of each institution at the network level in order to activate economies of scale, can provide support for the territory's economic development processes. The network, through isomorphism and collaboration, can overcome local limits, improving the quality of services and attracting and satisfying users. Even small museums can acquire the necessary professional skills, resulting in a reduction in unit costs for services, activities and materials needed for operation, a reduction in administrative costs and an increase in the quality and quantity of services offered to the public. ICT technologies, e-learning and e-government can guarantee the training of professionals for the management and maintenance of historical and cultural assets, as well as facilitating access to information for citizens and tourists, promoting the internationalization of content and the development of services and products, such as virtual tourist itineraries and online sales. The identification of a historical-cultural asset that acts as a driving force and catalyst for local development (a landscape and production context) can act as a reference point and meeting place for a wide range of related services and activities.

The situation of cultural assets in Camerino is closely linked to other urban systems. The recovery of these assets also depends on the restoration of the transportation infrastructure, which guarantees access to these areas, and the green infrastructure, which usually surrounds these monuments. In addition, the reconstruction of housing near these cultural landmarks can influence the preservation of the historic urban landscape and the attraction of new residents and tourists (Pierantoni et al., 2022).

Efforts to restore cultural assets should be carried out in sync with the revitalization of the local economy, especially tourism, which can serve as a lever to generate the funds needed for ongoing restoration. At the same time, creating jobs in restoration can help combat unemployment and depopulation by offering new economic opportunities for local residents (Pierantoni et al., 2019).

The current state of the cultural assets of Camerino and the Cratere Maceratese reflects the complex challenges faced by the region in its recovery from the earthquake. Although the destruction was extensive, there is potential for the restoration of these heritage sites to become a catalyst for the region's economic and social renaissance. However, this will require a coordinated approach that integrates recovery efforts with sustainable development policies and active community participation (Pierantoni et al., 2022). In the long term, the preservation of cultural assets will not only contribute to the continuity of the region's cultural identity, but will also serve as a basis for revitalizing tourism and attracting new investment. However, this will depend on an ongoing commitment from local and national authorities to provide the necessary resources and support to ensure that these monuments can be restored and maintained for future generations (Pierantoni et al., 2019).

Tourism

Before the 2016 earthquake, Camerino and the Cratere Maceratese region enjoyed a robust tourism-based economy, which was strongly supported by the rich cultural heritage, picturesque natural landscapes and the presence of one of the oldest universities in Europe. Cultural tourism, in particular, played a central role, attracting visitors interested in historic architecture, religious festivals and local traditions (Pierantoni et al., 2022). However, the earthquake caused significant devastation to the region's tourist infrastructure. Hotels, restaurants, museums and other tourist establishments suffered serious damage, many of which were forced to close permanently. Pierantoni et al., 2019 details how the destruction of historical monuments, combined with the loss of accommodation and services, resulted in a drastic drop in visitor numbers, directly impacting the local economy (p. 50).

In addition, the COVID-19 pandemic that followed the natural disaster exacerbated the situation, temporarily closing the few tourist establishments that were still operational and disrupting cultural events that attracted visitors. The combined impact of these crises has led to a deep economic crisis in the sector, with many tourism-related businesses facing bankruptcy or struggling to survive. The lack of a well-integrated green and blue infrastructure also represents a significant challenge for tourism in the region. Despite the vast natural areas that could attract tourists interested in ecotourism and outdoor activities, the lack of proper planning and maintenance of these areas limits their attractiveness. Many trails and natural areas, which could serve as complements to cultural tourism, remain underutilized or inaccessible due to damage and lack of resources for repair (Pierantoni et al., 2022).

Another critical aspect is the lack of connectivity and transportation, which makes it difficult to access remote tourist areas. The earthquake severely damaged roads and transportation infrastructure, isolating many of the region's attractions. As a result, visitors have difficulty reaching these sites, and rural tourism, which has the potential to be one of the pillars of local economic development, remains underexploited.

The reduction in the tourist flow not only directly affects the income of local businesses, but also jeopardizes the maintenance of the cultural and natural assets themselves. Without tourism, the financial resources needed to conserve and promote these sites are severely limited, creating a vicious cycle of degradation and loss of attractiveness (Pierantoni et al., 2019).

In addition, demographic change, with the exodus of young people in search of opportunities outside the region, impacts the ability to innovate and revitalize the tourism sector. The loss of a young population, which could bring new ideas and energy to the sector, leaves tourism stagnant and dependent on traditional models that don't meet the expectations of modern tourists (Pierantoni et al., 2022).

Integration with Other Urban Systems:

Tourism in Camerino is intrinsically linked to the preservation of cultural assets and the existence of a well-managed green and blue infrastructure. The recovery of tourism depends directly on the region's ability to restore its historical monuments and revitalize its natural areas. In addition, transport infrastructure is critical to improving access to tourist areas, especially in isolated rural areas that have great potential for ecotourism development. The revitalization of tourism is also connected to the wider economic recovery of the region. Increased tourist flows can generate revenue that can be reinvested in restoring cultural assets and improving public infrastructure. In addition, promoting sustainable tourism can help preserve the natural environment while providing economic benefits for the local population (Pierantoni et al., 2019).

Tourism in Camerino faces significant challenges, but it also has considerable potential to contribute to the region's economic and social recovery. The key to revitalizing tourism lies in integrating efforts to restore cultural assets, improve green and blue infrastructure and ensure adequate connectivity to facilitate access to the region's attractions (Pierantoni et al., 2022). In the long term, developing sustainable tourism that values both the region's cultural heritage and natural resources can transform Camerino into a benchmark destination for tourists interested in authentic and immersive experiences. However, this will require an ongoing commitment to innovation, sustainability and social inclusion, ensuring that all local residents can benefit from the growth of the tourism sector.

Energy

The energy infrastructure in Camerino and the Cratere Maceratese region is a critical aspect for the recovery and sustainable development of the region, especially after the 2016 earthquake. The local power grid, which was already showing signs of aging before the disaster, was severely damaged, resulting in frequent blackouts and difficulties in supplying power in many areas, both urban and rural. As detailed in Pierantoni et al., 2022, the damage to transmission lines and substations has created a significant challenge for restoring a stable and reliable energy supply.

In addition to the physical damage, the financial crisis that followed the earthquake, and later the COVID-19 pandemic, exacerbated the difficulties faced by the energy infrastructure. The lack of sufficient investment to modernize the electricity grid has kept the region in a constant state of vulnerability, with the infrastructure unable to support the demands of a modern economy or adapt to new energy technologies, such as renewable sources (Pierantoni et al., 2019).

Dependence on conventional energy sources, such as oil and gas, remains a significant problem. The region has been slow to transition to more sustainable energy sources, partly due to the lack of targeted public policies and the absence of economic incentives that promote the adoption of renewable energy technologies (Pierantoni et al., 2022). This situation leaves Camerino and the surrounding areas exposed to fluctuations in the price of fossil fuels and vulnerable to energy crises. Another critical issue is the energy efficiency of existing buildings and infrastructure. Most of the housing stock and public buildings in Camerino were not designed to be energy efficient, resulting in significant energy waste, especially during the winter months when energy consumption for heating peaks (Pierantoni et al., 2019). The lack of energy retrofit or modernization programs means that much of the energy consumed is wasted, increasing costs for residents and putting a strain on the already fragile energy infrastructure.

In addition, the infrastructure for power distribution in rural areas is particularly vulnerable. Transmission lines in mountainous areas are often affected by adverse weather conditions, such as storms and snow, which can cause power outages lasting days. The absence of redundancy and local power generation alternatives, such as micro-grids or distributed renewable energy sources, exacerbates the situation, leaving many communities without reliable access to energy (Pierantoni et al., 2022). The authorities' response has been limited mainly by the lack of financial resources and the complexity of the technical challenges involved in modernizing the infrastructure. Although there are plans to improve the resilience of the electricity grid and promote the adoption of renewable energy sources, the implementation of these plans has been slow, and progress so far has been insufficient to meet the region's needs (Pierantoni et al., 2019).

Integration with Other Urban Systems:

Camerino's energy infrastructure is closely linked to other urban systems, such as housing, transportation and smart technologies. The energy efficiency of buildings directly affects energy consumption, and the lack of modernization of buildings can increase pressure on the electricity grid, especially during periods of high demand. In addition, the transition to a more sustainable transport system, including electric vehicles, depends on a robust and reliable energy infrastructure. The integration of smart technologies in the management of the electricity grid is also crucial. The adoption of real-time monitoring systems and demand response technologies can optimize the use of the grid and reduce the occurrence of blackouts, as well as facilitating the integration of renewable energy sources (Pierantoni et al., 2022).

The current state of the energy infrastructure in Camerino and the Cratere Maceratese region is a reflection of the challenges faced by areas suffering from a lack of investment and a reliance on obsolete technologies. Modernizing the energy infrastructure is not only a necessity to guarantee a stable and reliable energy supply, but also an opportunity to promote sustainability and reduce the region's vulnerability to future crises (Pierantoni et al., 2019

In the long term, the transition to a more sustainable energy system, with greater reliance on renewable sources and the implementation of smart technologies, will be crucial to ensuring the region's resilience. This will require a coordinated effort between local, regional and national authorities, as well as the support of European funding programs and public-private partnerships. In addition, community education and engagement will be essential to ensure that residents are prepared to adopt and benefit from these changes.

Green Infrastructure

The green infrastructure in Camerino and the Cratere Maceratese region plays a vital role not only for environmental preservation, but also for the quality of life of residents and the region's resilience to natural disasters. The area is characterized by a wealth of parks, forests, and protected natural areas, which contribute to biodiversity, carbon sequestration, and provide essential recreational spaces for local communities. However, the 2016 earthquake, combined with years of poor maintenance and inadequate management, caused significant damage to these infrastructures, compromising their functionality and benefits (Pierantoni et al., 2022). Urban parks and green areas within cities, such as Camerino, are key to mitigating the effects of heatwaves and improving air quality, but many of these areas have suffered structural damage that has made them inaccessible or dangerous for public use. Vegetation in urban areas has been impacted by falling trees and the interruption of regular maintenance, resulting in green spaces that are no longer attractive or safe for the local population (Pierantoni et al., 2019).

In addition, forest areas in rural areas, which are crucial for preventing landslides and conserving biodiversity, have been seriously affected. The loss of forest cover, caused both by the earthquake and by inadequate management practices such as logging and lack of replanting, has increased the region's vulnerability to natural disasters. This is particularly worrying in a mountainous region like the Cratere Maceratese, where soil stability is essential for preventing secondary disasters such as landslides and floods (Pierantoni et al., 2022). The green infrastructure also includes ecological corridors that connect different natural areas, allowing the movement of fauna and maintaining biodiversity. However, these corridors have been disrupted due to disorderly construction and poorly planned urban development, which has not adequately considered the need for integration between natural areas. This fragmentation of ecological landscapes not only harms biodiversity, but also reduces the capacity of natural areas to provide essential ecosystem services, such as climate regulation and water purification (Pierantoni et al., 2019).

Another critical aspect of green infrastructure is its social function. Parks, gardens and public green areas are spaces where the community can gather, carry out recreational activities and promote social cohesion. However, with the damage caused by the earthquake and the lack of investment in restoring these spaces, many residents have lost access to these vital environments, which negatively impacts the mental health and general well-being of the population. In addition, the inappropriate use and irregular occupation of green areas, often due to a lack of suitable housing alternatives, has led to the degradation of these zones, further compromising their ecological and social function. The lack of integrated planning and effective management of these areas has allowed problems such as soil erosion and pollution to worsen, reducing the quality of the green spaces available (Pierantoni et al., 2022).

The response of local authorities and communities to the degradation of green infrastructure has been limited, partly due to a lack of financial and technical resources. Although there is recognition of the importance of these areas for urban and rural resilience, recovery actions have been piecemeal and insufficient to address the scale of the challenges (Pierantoni et al., 2019).

Integration with Other Urban Systems:

Green infrastructure in Camerino is deeply interconnected with other urban systems, including blue infrastructure, housing and public health. The integrity of green areas has a direct impact on stormwater management, influencing the ability of blue infrastructure to prevent flooding and mitigate the impact of heavy rainfall. Vegetation, especially in mountainous areas, plays a crucial role in absorbing water and preventing landslides, which is essential for protecting inhabited.

Green infrastructure also influences residents' quality of life, especially in terms of public health. Access to parks and recreational areas is vital for the physical and mental well-being of the population, and the lack of these spaces contributes to health problems such as stress, obesity and diseases related to sedentary lifestyles. In addition, the proximity of green areas to housing can significantly improve quality of life, providing a healthier and more pleasant environment for residents (Pierantoni et al., 2019).

The current state of the green infrastructure in Camerino and the Cratere Maceratese region reveals a scenario of degradation and lack of maintenance, exacerbated by the impacts of the 2016 earthquake. Preserving and restoring these areas is essential not only for environmental resilience, but also for the health and well-being of the local population. In the long term, the revitalization of green infrastructure can play a central role in the economic recovery of the region, especially through ecotourism and the creation of spaces that promote social cohesion (Pierantoni et al., 2022).

However, this will require an integrated approach that combines urban planning efforts with robust environmental policies and effective natural resource management. In addition, active community participation in the preservation and sustainable use of these areas will be crucial to ensure that green infrastructure can continue to provide its essential benefits to future.

Blue Infrastructure

Blue infrastructure, which covers water management systems, rivers, lakes and urban drainage systems, is crucial for the environmental sustainability and resilience of the Camerino region and the Cratere Maceratese. The region, which already faced challenges due to its mountainous geography, saw its blue infrastructure severely damaged by the 2016 earthquake, exacerbating existing problems and creating new vulnerabilities. Pierantoni et al., 2022 points out that after the earthquake, many essential structures, such as containment dams, sewage systems and drainage channels, were compromised, increasing the risk of flooding and water contamination (p. 93). Before the earthquake, water management in the region was already facing significant challenges due to aging infrastructure and a lack of investment in modernization. The sewage system, for example, was inadequate to cope with growing demand, resulting in frequent overflows and contamination of local waterways. The destruction caused by the earthquake only aggravated this situation, making the need for repairs and modernization urgent. According Pierantoni et al., (2019), many of these systems remain in a state of abandonment or with temporary repairs, which is not enough to guarantee the region's water security (p. 74).

In addition, the collapse of part of the blue infrastructure has increased the region's vulnerability to secondary natural disasters, such as landslides and floods. The absence of an effective drainage network has increased surface runoff, especially during heavy rains, which has caused soil erosion and further destruction of critical infrastructure (Pierantoni et al., 2022). Rural areas, in particular, have suffered from a lack of adequate water management infrastructure, which puts not only farms at risk, but also the very survival of the communities that depend on these resources. The inadequate management of water resources also negatively impacts the quality of drinking water in the region. Contamination of water sources due to damaged sewage systems is a constant risk, affecting public health and environmental sustainability. In addition, the scarcity of financial and technical resources to address these problems comprehensively means that many of the solutions implemented are temporary or palliative, failing to address the underlying causes of the problems Pierantoni et al., 2019).

Another important factor is the impact of tourism on the blue infrastructure. The region, which attracts visitors due to its natural landscapes and ecotourism, faces additional challenges in water management during the high tourist season. The increased demand for drinking water and the generation of sewage and waste during these periods puts an even greater strain on an already struggling system. Without a robust and modern blue infrastructure, the region risks degrading its natural resources, compromising both the health of residents and tourist attractiveness. The management of water resources in Camerino is also linked to the management of agricultural areas, where efficient irrigation is fundamental for sustainable production. However, the lack of modern irrigation systems and the deterioration of existing infrastructure have led to unsustainable farming practices that rely excessively on inefficient irrigation methods, contributing to soil degradation and reduced agricultural productivity (Pierantoni et al., 2022).

Integration with Other Urban Systems:

Blue infrastructure in Camerino is deeply interconnected with other urban systems, including green infrastructure, agriculture and public health. Proper water management is key to maintaining green areas and preventing natural disasters such as floods and landslides, which can occur in mountainous regions without effective water runoff management (Pierantoni et al., 2019). In addition, blue infrastructure is vital for agriculture, as efficient and sustainable irrigation depends on a well-maintained water network. The quality of drinking water is also directly related to public health, and the lack of an effective water management system can result in disease outbreaks and other health crises.

The current state of blue infrastructure in Camerino and the Cratere Maceratese region reveals a number of critical challenges that need to be addressed to ensure the region's environmental sustainability and resilience to natural disasters. The modernization and maintenance of this infrastructure is essential not only to protect water resources, but also to ensure the safety and well-being of local communities (Pierantoni et al., 2022). In the long term, the implementation of more sustainable and resilient water management systems, which integrate nature-based solutions and modern technologies, will be crucial to ensure the preservation of water resources and the protection of the environment. This will require a coordinated approach between local, regional and national authorities, as well as the active involvement of the community in the management and conservation of water resources.

Transportation

The transport system in the Cratere area is mainly characterized by the road network, often of old origin, which is highly influenced by the morphological difficulties and widespread fragmentation of urban settlements. The low density of these settlements results in long distances to be covered and high costs for the implementation of public collective mobility systems. In addition, there is complexity and slowness in accessing essential service centers, largely as a result of the lack of connectivity between the various modes of public transport and between private transport routes, a problem made even worse by the damage caused by the earthquake.

The region has few railway lines that don't connect all the urban centers and a fragmented extra-urban public transport system, characterized by a profusion of different companies with extremely fragmented bus routes, which don't have compatible timetables and often don't have junctions. Due to the disaggregation of the territory, individual daily movements are constant to reach services such as education and workplaces. These movements are usually made by private car, creating a dependency on it and a high number of private transport units per family.

There is also a difficulty in connecting to the supralocal scale, which is done exclusively via the Adriatic railroad, the airport and the port of Ancona, all options on the coast and already outside the cratere zone. The port and airport have very few destination options. This configuration represents a considerable slowdown in movement and limited use of public transport. The railroad linking Camerino to Castelraimondo was closed for good in 1956 and the route was taken by bus by the Contram company. Castelraimondo station is part of the Civitanova Marche-Fabriano line, which is of regional interest. It connects the inland area with the Adriatic coast, starting in Civitanova Marche and continuing into the province of Macerata before joining the Rome-Ancona line - near Albacina - finally arriving in Fabriano.

In general, the transportation system is highly dependent on fossil fuels. There are few options for slow mobility, consisting basically of a few disconnected cycle paths, due to the difficulty presented by the morphology of the terrain. Some trails in the countryside link natural tourist attractions, but they are not connected to urban centers, making it unsafe for cyclists to travel on the roads, which in many cases have no shoulder. The rugged terrain also makes it difficult to transport goods, increasing distances and traffic times, resulting in longer delivery times for raw materials and end products. The freight transportation infrastructure was also significantly affected by the earthquake. Logistics routes, which are essential for delivering goods and maintaining supply chains, were disrupted, resulting in delays and increased transportation costs. This negatively affected local commerce and industry, which were already struggling due to the economic crisis caused by the earthquake and subsequent pandemic (Sargolini et al. 2022).

Connectivity and accessibility represent a precondition for the development of the area. SNAI reports the need to increase accessibility to internal areas, especially to basic services such as citizenship, education and health. According to Pierantoni et al. (2019), this result can be achieved in two ways: a) reinforcing and rethinking the supply of services, b) improving mobility by reducing the effective movement times to access the services available in the hubs.

Camerino's transport infrastructure is deeply interconnected with other urban systems, such as tourism, the local economy and housing. Efficient transportation is essential to the functioning of all other systems, ensuring that residents can access services, employment opportunities and cultural and recreational activities. In addition, an efficient transportation network is vital for tourism, allowing visitors to explore the region and contribute to the local economy. Mobility is also linked to quality of life, especially in the context of housing. Residents who live in areas with good connectivity have better access to jobs, education and health services, which is crucial for overall well-being. The lack of accessible public transportation exacerbates social and economic inequality, especially for the most vulnerable populations.

The main objective of this system is therefore to increase physical connectivity through the implementation of intelligent, sustainable and integrated mobility and transportation systems. This initiative aims to reduce the conditions of isolation and marginalization typical of inland areas, guaranteeing quick access to service centers and connecting municipalities with each other and with supra-local routes. The urgency of rehabilitating the infrastructure damaged by the earthquake is highlighted by the need to improve internal connections between urban centers and between them and service centers. At the same time, it is essential to reorganize public transport, introducing multimodal and information nodes to facilitate access and tourism planning. These nodes should facilitate connections between municipal, regional, national and international systems, both by public and private transport. Top priority should be given to modernizing infrastructure of strategic importance, with the aim of improving slow and fast connections and facilitating the connection between rail and public transport. The diversification of means of transport and their interconnection can stimulate demand for less polluting means, and encouraging the use of clean energy means can be directly related to energy generation. An improved transportation system not only attracts tourists, but also solves the challenges that new businesses face, considering mobility as a significant obstacle to the development of their activities. To facilitate tourist information and transportation management, the implementation of an integrated information system for local and suburban public transportation is highly recommended.

Smart

Smart technologies represent a significant opportunity to improve efficiency, resilience and quality of life in Camerino and the *Cratere Maceratese* area. However, the implementation of these technologies in the region is still in its early stages, with large gaps in communication infrastructure and limited adoption of advanced technological solutions. Pierantoni et al., 2022highlights that while there is considerable potential for the application of smart technologies, the existing infrastructure is not equipped to support this transformation (p. 108). Before the earthquake, the region was already facing challenges in terms of digital connectivity, with many rural and mountainous areas lacking adequate access to high-speed internet. After the disaster, these challenges were magnified, with damage to communication infrastructures and the interruption of essential services. The lack of a robust communications network makes it difficult to implement intelligent solutions, such as real-time monitoring systems, which are essential for efficient resource management and emergency response (Pierantoni et al., 2019).

In addition, the adoption of smart urban management technologies, such as traffic sensors, efficient street lighting systems and waste management platforms, is practically non-existent in the region. This results in less efficient urban management, wasted resources and a limited capacity to respond to urban problems in real time. The lack of investment in technological infrastructure, combined with the absence of clear public policies that encourage the adoption of these technologies, contributes to the region's stagnation when it comes to technological innovation (Pierantoni et al., 2022). Another significant challenge is the digital literacy of the population. The adoption of smart technologies depends not only on infrastructure, but also on the population's ability to use them effectively. In a region where the population is ageing and the migration of young people in search of better opportunities is a reality, there is greater resistance to adopting new technologies. This resistance, combined with the lack of education and training programs in technology, prevents the successful implementation of intelligent solutions that could benefit the community as a whole.

The lack of integration between different urban systems is also a barrier to the development of a smart city. Transportation systems, waste management, environmental monitoring and emergency services operate independently, without an integrated platform that allows for efficient and coordinated management. Implementing an intelligent urban management network that connects these systems is essential to improving the resilience and quality of the services offered to citizens (Pierantoni et al., 2019).

Smart technologies have the potential to transform the way urban systems work in Camerino, improving energy efficiency, waste management, transportation and public safety. The integration of smart technologies can optimize the use of resources, reduce operating costs and increase the city's ability to respond quickly to crises and changes in population demands (Pierantoni et al., 2022). Energy infrastructure, for example, can benefit from smart technologies for real-time monitoring and demand management, which would reduce the risk of blackouts and enable a smoother transition to renewable energy sources. In transportation, traffic sensors and route management systems can improve urban mobility, reducing congestion and increasing safety on the roads.

The development of a smart city in Camerino and the *Cratere Maceratese* region represents a significant opportunity to modernize urban services and improve residents' quality of life. However, this will require substantial investment in communication infrastructure, digital education and public policies that encourage the adoption of smart technologies. In the long term, the successful implementation of these technologies can transform the region, making it more resilient, sustainable and attractive to new investments and young people (Pierantoni et al., 2019).

Trade and Industry

Trade and industry in Camerino and the *Cratere Maceratese* region have been pillars of the local economy, sustaining jobs and contributing to the region's economic development. However, the 2016 earthquake, followed by the financial crisis and the COVID-19 pandemic, has had a devastating impact on these sectors. Many small and medium-sized businesses were forced to close, resulting in a rise in unemployment and the emigration of young people in search of opportunities in other regions. According to Pierantoni et al., 2022, the industrial infrastructure has been severely damaged, and the lack of investment in recovery has made it difficult to revitalize the sector (p. 110).

Local industry, which was already facing challenges before the earthquake due to a lack of innovation and modernization, was further weakened by the destruction of facilities and the disruption of supply chains. Many factories and production units were destroyed or damaged, and the costs of reconstruction, combined with economic uncertainty, prevented a full resumption of industrial activities in the region. The trade sector, for its part, has suffered from the fall in consumption and the loss of purchasing power of the population, exacerbated by unemployment and the economic crisis (Pierantoni et al., 2019). In addition, the lack of an efficient transport infrastructure limits the capacity of trade and industry in the region. The difficulty of accessing production areas and the lack of connectivity with regional and national markets reduce the competitiveness of local companies, making it difficult to attract new investments or expand existing businesses. Logistics infrastructure has also been compromised by the earthquake, which directly impacts companies' ability to operate efficiently and maintain stable supply.

Another challenge is the lack of innovation and adoption of advanced technologies in the industrial sector. Many companies in the region still rely on traditional production methods that are not competitive in a globalized market. The lack of investment in research and development, as well as the absence of partnerships with universities and innovation centers, hinders the growth and modernization of the industrial sector, leaving it vulnerable to economic and technological changes (Pierantoni et al., 2022). The situation in the commercial sector is also worrying. With the destruction of commercial areas and the reduction in the number of visitors due to the earthquake, many stores and retail establishments have closed their doors. The recovery of this sector has been slow, and the lack of a clear strategy to revitalize commercial areas leaves many of these regions in a state of stagnation, with little or no economic activity (Pierantoni et al., 2019).

Commerce and industry in Camerino are intrinsically linked to other urban systems, such as transportation, housing and energy. Efficient transportation infrastructure is essential for industry to function, facilitating the movement of goods and inputs. In addition, the availability of reliable, low-cost energy is crucial for industrial operations, especially in sectors that require high energy consumption. Revitalizing the housing sector, meanwhile, can help attract and retain workers in the region by providing affordable, quality housing close to industrial centers. Modernizing industry can also benefit other systems, such as the local economy and technological innovation. The development of partnerships between universities and companies can promote the transfer of knowledge and the adoption of advanced technologies, increasing the competitiveness of the industrial sector and contributing to regional economic growth (Pierantoni et al., 2019).

The current state of commerce and industry in Camerino and the *Cratere Maceratese* reflects the economic and structural challenges the region faces in its post-earthquake recovery. Revitalizing these sectors is essential for the region's economic development, but will require significant investment in infrastructure, innovation and modernization. In the long term, strengthening trade and industry can create new job opportunities, stimulate economic growth and attract new investment to the region, contributing to recovery and sustainable development (Pierantoni et al., 2022).

Housing

The residential context of the crater region is mainly characterized by small urban centers, distributed capillarily throughout the territory. These centers include historic towns located high up in the hills, as well as some more recent towns in the valleys and industrial areas adjacent to the main communication routes. In the case of the municipality of Camerino, we have the historic center at altitude which was home to of the population until 2016. After the earthquake, the entire historic center was declared a red zone and remains so to this day. The SAEs expanded the urban boundary mainly to the north of the city, to areas like San Paolo, but also to the south like *Vallicelle;* also taking with them commerce, essential services and the university. Almost half of Camerino's residents before the earthquake were students. This reflects a large annual migration flow and an opportunity to use the built heritage for rent. With the earthquake, these students were relocated to areas on the outskirts of the city. However, with the pandemic and distance learning.... The quality of housing is also a significant problem. Much of the housing stock is in the historic center, which implies the need to renovate historic buildings that, for the most part, still fail to meet modern standards of seismic safety and energy efficiency.

Another challenge is the availability of affordable housing. The destruction of many housing units, combined with the slow pace of reconstruction, has resulted in a shortage of available housing, which has increased prices and made access to housing more difficult, especially for the most vulnerable populations. In addition, the lack of adequate emergency housing during the recovery period has increased the pressure on affected families, many of whom have been forced to live in precarious conditions or seek shelter outside the region (Pierantoni et al., 2019). The housing situation is also complicated by the lack of integrated urban planning. In many areas, reconstruction has taken place in an uncoordinated way, without considering the need to create sustainable and resilient communities. The lack of strategic planning means that many of the new constructions are not aligned with the future needs of the population, nor with the principles of sustainability and resilience, which could lead to new problems in the future.

The housing sector in Camerino is deeply interconnected with other urban systems, such as green infrastructure, transportation and public services. The availability of affordable and safe housing is essential for attracting and retaining residents, which is crucial for the economic and social revitalization of the region. In addition, integrating housing with green and blue infrastructure can create more sustainable and resilient communities, improving quality of life and reducing environmental impact (Pierantoni et al., 2022). Mobility is also closely linked to housing. Creating compact, interconnected communities with easy access to public transportation and essential services is vital to ensuring that residents can access employment, education and health opportunities. In addition, modernizing housing with smart technologies can improve energy efficiency and reduce living costs, contributing to community sustainability and resilience.

The current state of the housing sector in Camerino and the Cratere Maceratese region highlights the urgent need for an integrated approach to housing reconstruction and modernization. The creation of a long-term strategy that includes the modernization of existing buildings, the construction of new resilient and affordable housing, and the integration of sustainability and resilience principles into urban planning is essential to secure the future of the region (Pierantoni et al., 2019).

The revitalization of the housing sector can contribute significantly to the economic and social recovery of the region, creating new job opportunities, attracting new residents and improving quality of life. In the long term, the creation of sustainable and resilient housing communities can transform Camerino into a model of post-disaster recovery and sustainable development (Pierantoni et al., 2022).

Agriculture

Agriculture is a fundamental sector for the economy and culture of the Cratere Maceratese region, and plays a crucial role in preserving the rural landscape and local food security. However, the 2016 earthquake, combined with a lack of investment in modernization and demographic change, has severely impacted the agricultural sector in the region. As highlighted in Pierantoni et al., 2022, many farmers lost their farms, equipment and supporting infrastructure due to the disaster, resulting in a significant drop in agricultural production (p. 115). Before the earthquake, agriculture in the region was already facing challenges related to a lack of innovation and modernization of farming practices. Reliance on traditional methods, combined with a lack of technical and financial support, limited farmers' ability to increase productivity and compete in an increasingly globalized market. The destruction caused by the earthquake exacerbated these difficulties, leaving many farmers without the resources to rebuild their operations or adopt new technologies that could improve the efficiency and sustainability of production (Pierantoni et al., 2019).

In addition, the infrastructure supporting agriculture, such as irrigation systems, rural roads and distribution centers, has been severely damaged. The lack of access to reliable water for irrigation, combined with increased soil erosion and the degradation of farmland, has resulted in a decrease in productivity and an increase in production costs. Many farmers face difficulties accessing markets due to damaged transportation infrastructure, which limits their opportunities to sell their products and increases their dependence on intermediaries, who often pay low prices (Pierantoni et al., 2022). Demographic change in the region also impacts agriculture. The depopulation of rural areas, caused by the migration of young people to the cities in search of opportunities, has resulted in an aging agricultural population. This puts the continuity of traditional farming practices and the transfer of knowledge between generations at risk. In addition, the lack of young farmers makes it difficult to adopt new technologies and more sustainable farming practices, which are essential for the sector's resilience (Pierantoni et al., 2019).

Another significant challenge is the lack of access to finance for farmers. The economic crisis, exacerbated by the earthquake, has reduced the availability of credit and government support programs, which prevents many farmers from making the necessary investments to modernize their operations or expand production. Without access to capital, farmers cannot adopt more efficient farming practices or buy new equipment, which leaves them at a disadvantage compared to competitors who do have access to these.

Agriculture in Camerino is deeply interconnected with other urban systems, such as green infrastructure, water and the local economy. The availability of water resources and the effective management of blue infrastructure are essential to ensure the sustainability of agricultural production. The degradation of green infrastructure, such as forests and grazing areas, directly impacts soil quality and agricultural production capacity (Pierantoni et al., 2022). In addition, agriculture plays an important role in preserving the cultural landscape and promoting rural tourism, which can be an additional source of income for farmers. The creation of agricultural cooperatives and the integration of agriculture with other economic activities, such as artisanal food production and tourism, can help revitalize the sector and strengthen the local economy (Pierantoni et al., 2019).

The current state of agriculture in Camerino and the Cratere Maceratese region reflects the challenges facing the sector in an environment of post-disaster recovery and economic change. The modernization of agriculture, combined with financial and technical support for farmers, will be essential to ensure the sustainability and resilience of the sector. In the long term, the integration of sustainable agricultural practices, the revitalization of rural areas and the promotion of rural tourism can transform agriculture into an engine of economic and cultural development in the region.

The revitalization of agriculture will also depend on an integrated approach that considers the sustainable management of natural resources, the modernization of agricultural infrastructure and continued support for farmers. The creation of training programs and the promotion of innovative technologies will be crucial to ensure that the next generation of farmers is prepared to face the challenges ahead and to seize the opportunities of a revitalized agricultural sector (Pierantoni et al., 2022).

4.4.2 Process Model

Cultural Assets

The 2016 earthquake caused widespread destruction, directly affecting monuments that are symbols of local cultural heritage. As highlighted in Pierantoni et al., 2022, many of these sites, such as churches, palaces and medieval fortifications, were severely damaged, with several of them remaining in a state of ruin years after the disaster due to the lack of adequate resources for their restoration. Camerino's cathedral, for example, which served as one of the main spiritual and cultural reference points, was partially destroyed, compromising not only the physical structure but also the social fabric of the community, which has always seen these monuments as an extension of its own identity. Furthermore, the destruction of historic sites such as the Palazzo Ducale not only damages collective memory, but also weakens the tourist attractiveness of the region, which relies heavily on its cultural heritage (Pierantoni et al., 2019).

Damage to cultural assets is not restricted to large monuments. Small historic buildings, such as rural chapels and centuries-old farmhouses, which dot the landscape of the region's interior, were also devastated. These buildings, although less well known, are equally important for the conservation of local cultural identity and for maintaining the rural character of the region. The loss of these structures has led to a homogenization of the landscape, where the architectural diversity that once characterized rural areas is gradually being replaced by modern and less historically significant buildings (Pierantoni et al., 2022).

The situation is aggravated by the slow response of the authorities in initiating recovery projects and by the exhaustion of financial resources earmarked for restoration. The funds allocated for reconstruction have been insufficient to cover all needs, and many of the damaged monuments continue to deteriorate while awaiting intervention (Pierantoni et al., 2019). In addition, the complexity of bureaucratic processes has made it difficult to access funding, further delaying recovery efforts.

Another critical aspect is the loss of intangible heritage, which is often intrinsically linked to damaged physical sites. The traditions, festivities and rituals that develop around these cultural spaces risk disappearing as the sites that house them remain inactive or are destroyed. The loss of these cultural practices could have a long-term impact on social cohesion and the sense of collective identity, especially in a region that is already facing significant challenges due to depopulation and an ageing population (Pierantoni et al., 2022).

In addition, the impact on the local economy is significant. Cultural tourism, which largely depended on the preservation of these monuments, suffered a drastic drop after the earthquake. The closure of museums, the interruption of historical tours and the inaccessibility of cultural landmarks resulted in a substantial reduction in the flow of visitors, directly affecting the livelihoods of countless small businesses that depended on this sector (Pierantoni et al., 2019).

The loss of cultural assets also has a profound psychological effect on the local population. For many residents, especially those whose families have lived in the area for generations, historical monuments and buildings are tangible symbols of continuity and identity. Their destruction not only represents a physical loss, but also a rupture in the community's historical continuity, leading to feelings of disorientation and collective loss (Pierantoni et al., 2022).

Finally, the loss of skilled labor and the exodus of young people from the region make restoration efforts even more difficult. The absence of skilled artisans, such as bricklayers and carpenters with knowledge of traditional building techniques, prevents the authentic restoration of these historic monuments. This decline in traditional skills, combined with the lack of young people who can be trained in these arts, puts the long-term preservation of the region's cultural authenticity at risk (Pierantoni et al., 2019).

If no significant intervention is carried out for the recovery and preservation of cultural assets in Camerino and the Cratere Maceratese region, the future of these heritages will be marked by continued and possibly irreversible deterioration. The monuments and historic buildings that suffered damage in the 2016 earthquake will continue to deteriorate, compromising not only the physical integrity of these structures, but also the cultural and historical value they represent. As discussed by Pierantoni et al, 2022, the lack of financial resources and prolonged bureaucracy have prevented restoration projects from being carried out, and this inertia could result in the definitive loss of many of these heritage sites. In the scenario where no action is taken, it is likely that many of the cultural assets that are currently in a critical state will end up collapsing completely, making it impossible to restore them in the future. This would not only represent an irreparable loss to local history and culture, but would also negatively affect cultural tourism, which depends on the existence and preservation of these sites Pierantoni et al., 2019 points out that the continued degradation of historical monuments will lead to a significant reduction in tourist flow, exacerbating the economic crisis in the region. The absence of interventions will also affect local communities, who will see their cultural and historical ties weakened. The loss of churches, palaces and other landmarks that serve as centers of identity and social cohesion could result in a growing alienation of the population from their heritage. Without these tangible symbols of their history and culture, future generations may lose their sense of belonging and community pride, which can lead to an increase in rural exodus and the emptying out of local communities.

In addition, the lack of ongoing maintenance and preventative measures will increase the risk of further damage in future events, such as other earthquakes or adverse weather conditions. The lack of investment in monitoring technologies and the training of skilled labor for the conservation of these cultural assets will result in a reduced capacity to respond to new challenges, exacerbating the vulnerability of the region's cultural heritage Pierantoni et al., 2022).

From an economic point of view, the deterioration of cultural assets will have devastating effects. Tourism, which is a vital source of income for the region, will continue to decline as historic sites become less accessible or disappear altogether. The reduction in tourism will directly affect the local economy, especially sectors such as hotels, restaurants and commerce, which rely heavily on visitors. In addition, the loss of jobs in the tourism sector will exacerbate unemployment, contributing to depopulation and economic stagnation (Pierantoni et al., 2019).

Socially, the loss of cultural heritage can lead to a weakening of the traditions and cultural practices associated with these sites. Festivals, religious rituals and other forms of cultural expression that depend on the existence of these spaces can disappear, resulting in an erosion of the region's intangible heritage. The continuity of these traditions is fundamental to the social cohesion and cultural identity of local communities, and their loss could have profound and lasting consequences.

Without immediate and coordinated intervention, the future of cultural assets in Camerino and the Cratere Maceratese region is bleak. The continued deterioration of these structures will not only result in the irreparable loss of historical heritage, but will also have profound economic and social impacts that will jeopardize the recovery and sustainable development of the region. In the long term, a lack of action could turn this area, rich in history and culture, into a tragic example of neglect and abandonment (Pierantoni et al., 2022).

Tourism

If no action is taken to revitalize the tourism sector in Camerino and the Cratere Maceratese region, the decline of this sector, which is already underway, will deepen significantly. Tourism, which is one of the region's economic pillars, has already been severely affected by the damage to infrastructure and the loss of cultural assets caused by the 2016 earthquake. Without coordinated efforts to recover and promote tourism, the sector will continue to shrink, with devastating economic consequences for the region (Pierantoni et al., 2022). The lack of investment in tourist infrastructure, such as hotels, restaurants and attractions, will result in a low-quality tourist experience, unable to attract visitors. In addition, the continued deterioration of cultural assets and the lack of maintenance of natural areas will further reduce the region's attractiveness as a tourist destination. Pierantoni et al., 2019 warns that continued neglect in revitalizing tourism could lead to the region losing its competitiveness in relation to other destinations, both national and international (p. 60).

Without intervention, deteriorated transport links and inadequate blue and green infrastructure will continue to represent significant barriers to tourism development. The lack of accessibility to tourist attractions, combined with the absence of adequate services and facilities, will make it difficult to attract new visitors and retain those who already know the region. The stagnation of tourism will contribute to a drop in economic flow, directly harming the sectors dependent on this.

The decline in tourism will have a direct impact on the local economy, especially on small and medium-sized businesses that depend on visitors. Sectors such as hotels, shops and restaurants will suffer significant losses, resulting in bankruptcies, increased unemployment and a drastic reduction in household income. This situation could lead to a vicious cycle of economic decline, where the lack of tourists further weakens the region's ability to recover and attract new investment (Pierantoni et al., 2022). Socially, the loss of tourism will affect community life and cultural preservation. Cultural tourism, in particular, plays an important role in maintaining and promoting local traditions. Without tourists to sustain these activities, many cultural events and festivals could disappear, leading to an erosion of the traditions and cultural practices that are central to the region's identity (Pierantoni et al., 2019).

Without intervention, the future of tourism in Camerino and the Cratere Maceratese is one of continued decline. The lack of investment in infrastructure, the deterioration of cultural assets and the lack of active promotion of the destination will result in an irreparable loss for the region's economy and culture. In the long term, this neglect could lead to the economic and social isolation of the region, seriously jeopardizing the prospects for recovery and development.

Energy

If no action is taken to modernize and strengthen the energy infrastructure in Camerino and the Cratere Maceratese region, the energy supply system will continue to be vulnerable and insufficient to meet the region's current and future needs. The power grid, already weakened by damage from the 2016 earthquake, will face an increasing risk of failures and outages, especially during extreme weather events or periods of high demand (Pierantoni et al., 2022). Continued reliance on an outdated power grid and conventional energy sources such as fossil fuels will leave the region exposed to energy crises and increase energy costs for local residents and businesses. Without investment in renewable energy sources such as solar and wind, the region will miss the opportunity to reduce its carbon footprint and become more energy self-sufficient. In addition, the lack of infrastructure to support the adoption of smart energy technologies, such as smart electricity grids and real-time energy meters, will hinder the modernization and efficiency of the system (Pierantoni et al., 2019). The lack of energy efficiency programs, especially in public and residential buildings, will result in excessive energy consumption and high operating costs. Without actions to improve the energy efficiency of existing buildings and to promote the construction of low-energy buildings, the region will continue to waste valuable resources, which could be reinvested in other essential areas, such as health and education.

The lack of a robust and modern energy infrastructure will have significant economic impacts, especially in the industrial and commercial sector. Companies that depend on a reliable energy supply may face operational difficulties, which could lead to reduced production, loss of competitiveness and, eventually, business closures. The inability to attract new industries and investments, due to the lack of an adequate energy infrastructure, will limit the opportunities for economic growth in the region (Pierantoni et al., 2022). Socially, the lack of access to reliable and affordable energy can exacerbate social and economic inequalities. Rural and more isolated communities, which already face challenges due to a lack of infrastructure, will be the most affected by the continuation of an inadequate energy system. Lack of energy can impact quality of life, making it difficult to access essential services such as heating during the winter and operating medical equipment (Pierantoni et al., 2019).

Without urgent intervention to modernize and strengthen the energy infrastructure in Camerino and the *Cratere Maceratese*, the region will continue to face significant challenges that will compromise its economic development and the quality of life of its residents. The transition to a more sustainable and efficient energy system is essential to ensure the region's resilience to future crises and to promote sustainable and inclusive economic.

Green Infrastructure

The absence of interventions in the recovery and maintenance of green infrastructure in Camerino and the Crater region will lead to a continued deterioration of natural areas and green spaces, compromising environmental sustainability and quality of life in the region. Green infrastructure, which includes parks, forests and protected natural areas, plays a vital role in mitigating climate change, regulating temperature and promoting biodiversity. However, without coordinated actions for their preservation, these areas will continue to be degraded (Pierantoni et al., 2022). The lack of regular maintenance and investment in urban green areas will result in public spaces becoming less and less attractive and more dangerous for the population. Parks and gardens, which should serve as places of recreation and well-being, will become neglected areas, marked by uncontrolled vegetation, deteriorated infrastructure and a reduction in public safety. The absence of requalification projects for these areas contributes to the loss of their social and ecological function (Pierantoni et al., 2019).

In rural areas, the degradation of green infrastructure will increase the region's vulnerability to natural disasters such as landslides and floods. The loss of forest cover, combined with unsustainable agricultural practices, will lead to soil erosion and ecosystem degradation. Without proper management of natural areas, the region will lose its ability to provide essential ecosystem services, such as regulating the water cycle and maintaining air quality.

Economic and Social Impacts:

The deterioration of the green infrastructure will have negative economic and social impacts. The reduction in the quality of natural and green areas will result in a decrease in ecotourism, which is an important source of income for the region. The decline in tourism will directly affect the local economy, damaging businesses that depend on this activity and reducing employment opportunities. In addition, the loss of green areas will affect the quality of life of residents, who will have less access to recreational spaces and a healthy environment (Pierantoni et al., 2022). Socially, the degradation of green infrastructure can lead to an increase in inequalities, especially in densely populated urban areas. Low-income communities, which already face challenges related to lack of access to services and basic infrastructure, will be the most affected by the loss of green spaces, which can exacerbate public health problems such as obesity, respiratory diseases and stress (Pierantoni et al., 2019).

Without effective intervention, the green infrastructure in Camerino and the Cratere Maceratese region will continue to deteriorate, compromising environmental sustainability and quality of life in the region. The preservation and revitalization of these areas are essential to ensure the region's resilience to natural disasters, promote biodiversity and improve the well-being of the population. In the long term, integrating green infrastructure into urban and rural planning will be crucial for the sustainable development of the region.

Blue Infrastructure

The lack of intervention to restore and modernize the blue infrastructure in Camerino and the Crater region will result in a series of problems related to the inadequate management of water resources and the increased vulnerability of the region to natural disasters such as floods and droughts. The blue infrastructure, which includes drainage systems, sewage networks and water management, has already been significantly damaged by the 2016 earthquake. Without action to repair and upgrade this infrastructure, the region's ability to deal with climate and environmental challenges will continue to decline (Pierantoni et al., 2022). The drainage system, which is crucial for preventing flooding in urban and rural areas, is at risk of continuous collapse due to a lack of maintenance and modernization. The inability to properly manage water runoff will result in frequent flooding, which will cause additional damage to infrastructure and property, as well as increasing the risk of landslides in mountainous areas. Pierantoni et al. (2019) emphasizes that the lack of intervention in blue infrastructure could result in recurrent water crises, which will affect both drinking water supplies and agricultural irrigation (p. 74). In addition, the contamination of water sources due to the deterioration of the sewage system and the lack of modern treatment plants will pose a serious risk to public health. Without investment in water treatment technologies and efficient sewage systems, water quality in the region will continue to deteriorate, which could lead to outbreaks of waterborne diseases and widespread environmental degradation.

The continued deterioration of the blue infrastructure will have serious economic consequences for the region. The inability to properly manage water resources will affect agriculture, which depends on a reliable water supply for irrigation. The reduction in agricultural production due to water scarcity and soil degradation will result in significant economic losses for farmers and the local economy as a whole (Pierantoni et al., 2022). Socially, the lack of adequate blue infrastructure will affect the health and well-being of the population. The contamination of drinking water and the lack of adequate basic sanitation will increase the incidence of disease, especially among the most vulnerable populations. In addition, frequent flooding and environmental degradation could force communities to migrate, exacerbating depopulation and social isolation in the region (Pierantoni et al., 2019).

Without intervention, the blue infrastructure in Camerino and the Crater will continue to deteriorate, with disastrous consequences for water management, agriculture and public health. Modernizing and expanding this infrastructure is essential to ensure the region's resilience to natural disasters and to promote sustainable development. In the long term, integrating nature-based solutions and modern technologies into water management will be crucial to protecting the population and the environment.

Transportation

The transportation infrastructure in Camerino and the Crater area is essential for the connectivity, accessibility and economic development of the region, especially in a mountainous area where mobility is a constant challenge. Camerino doesn't result as a services hub in the SNAI classification, but it is highly attractive, offering important services such as the University of Camerino and the Santa Maria della Pietà hospital. The 2016 earthquake caused significant damage to roads, bridges and other transportation infrastructure, exacerbating the isolation of rural communities and hindering access to essential services. According to Sargolini et al. (2022), many secondary roads, vital for connecting small villages to urban centers, were severely damaged or destroyed, leaving entire areas inaccessible for long periods. The lack of proper maintenance and anti-seismic design before the earthquake had already left the transportation infrastructure vulnerable, and the destruction caused by the disaster only made matters worse. Many of the region's transportation systems were built decades ago and have not been updated to meet modern needs or to withstand extreme natural events. As a result, the current transportation network is insufficient to ensure safe and efficient mobility, especially in emergency situations (Pierantoni et al. 2019).

With regard to the railroad, there are no plans to reopen it. After the 2016 earthquake, plans were approved for the electrification of the Civitanova-Fabriano tract (Cipe - Contratto di Programma 2017-2021), which includes the Castelraimondo station, the closest to Camerino. The contract also included its seismic upgrading and the speeding up of some sections of the line, as well as new stations in Macerata and Tolentino to facilitate access to university campuses.

An important initiative for the accessibility of the inner areas of the Marche region is the Pedemontana, a project thought up over 40 years ago by Berlusconi and Lunardi in the Legge-Obiettivo of the "Sblocca-Italia" Law. The Pedemontana road was born from the idea of creating an artery parallel to the Adriatic road. The project initially came from the Marche-Umbria Quadrilateral in 2001, although the construction sites only began in 2014. The aim of the Quadrilateral is to enhance the Ancona-Perugia and Civitanova-Foligno routes and create the Pedemontana road which, as its name suggests, runs through the Appennino border area, joining the two routes mentioned between Fabriano and Muccia. Currently, the first phase of the project is almost complete, passing through Camerino. Piano Infrastrutture Marche 2032 intends to extend this route along the Appennino to the north and south, linking Ascoli Piceno to Urbino.

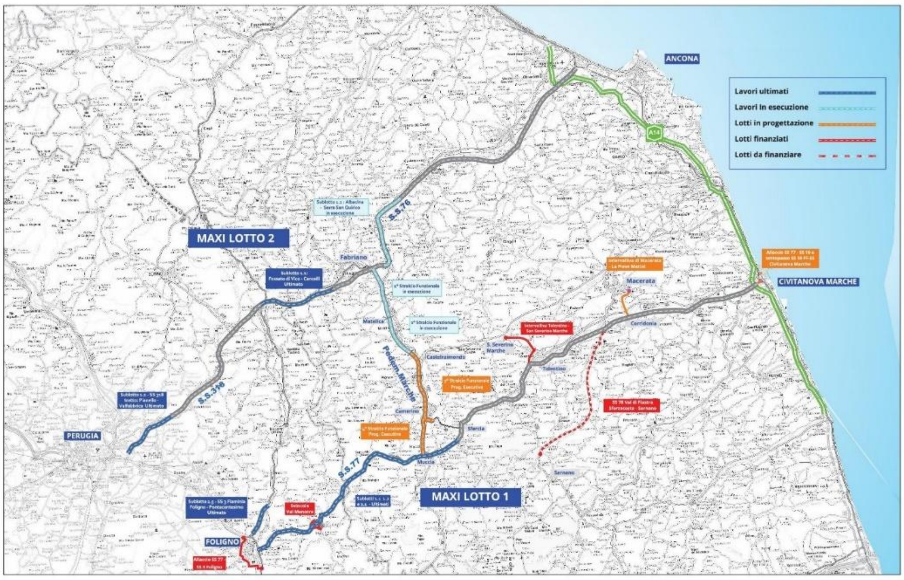


Figure 56: Marche-Umbria Quadrilateral. Source: https://www.mcnet.tv/pedemontana-fabriano-muccia-completamento-entro-il-2023/

The *Piano Infrastrutture "Marche 2032"* is a contribution to the transformation of mobility infrastructure, considered in the plan as a precondition for social, environmental and economic development and well-being. The plan has four principles: sustainability, safety, inter-modality and interconnection. It envisages moving from a "comb" structure to a network, with advantages for the environment such as CO2 reduction by reducing travel times. To this end, the project envisages reconnecting Ancona with the internal areas and with the whole of Europe, building a diagonal TEM-T European corridor to connect the Balkans and the East with the Iberian Peninsula and the Atlantic through water-rail-rail inter- and multimodality. Connecting the Port of Ancona with the Tyrrhenian ports of Civitavecchia, Pionbino, Livorno and La Spezia to facilitate the transportation of goods and passengers. In this way, international commercial traffic becomes more advantageous from the point of view of travel times and transportation costs. It also aims to create a mesh network for roads and railroads (the Ascoli-Porto d'Ascoli-Civitanova and Marche-Fabriano Railway Ring which should continue to Urbino, crossing Pergola along the Subappenninico route reactivated in 2021 for tourist purposes, to Fano with the Adriatic) and to create modern and efficient infrastructures for sustainable development.

The region faces a serious shortage of public transport services, forcing residents to rely on private vehicles and increasing transportation costs. Public transportation on wheels lacks initiatives for change. The disconnection of the system contributes to the isolation of the most vulnerable populations, such as the elderly and people with reduced mobility, who have little or no alternative means of transportation (Sargolini et al. 2022) and disadvantages international tourism by excluding tourists who have no intention of renting a car.

Furthermore, the lack of efficient connectivity between Camerino and other neighboring cities or regions represents a significant obstacle to economic development. Geographical isolation limits trade, tourism and the attraction of new investment, essential factors for the economic revitalization of the region after the disaster. Inadequate transportation infrastructure also hinders rapid response in emergency situations, where quick access to affected areas is crucial (Ciorra et al. 2024). Another major challenge is the integration of different modes of transportation. The absence of an integrated transportation network that combines vehicles, bicycles and walking makes mobility more difficult and inefficient. Poorly designed or damaged roads and streets do not offer adequate safety for pedestrians and cyclists, limiting sustainable transportation options. In addition, the lack of infrastructure for electric vehicles, such as charging stations, hinders the adoption of greener transportation, which could contribute to reducing carbon emissions in the region (Pierantoni et al. 2019).

In the long term, the creation of an efficient, safe and sustainable transport network will be essential for the recovery and revitalization of the region, facilitating access to services and opportunities (Sargolini et al. 2022). The modernization of transport infrastructure must include the reconstruction of roads and bridges, the expansion of public transport services and the promotion of sustainable modes of transport, such as cycle paths and electric vehicles. In addition, integrating smart technologies for traffic management and improving road safety will be crucial to ensure that the region is prepared for future challenges (Ciorra et al. 2024).

Without significant interventions to modernize and expand transport infrastructure, the situation will become increasingly critical, further limiting mobility, economic development and accessibility to essential services. This will negatively affect the region's ability to recover economically and attract new investment, as well as reinforcing the conditions of isolation of peripheral and outermost communities, hindering access to markets, health services and education, exacerbating depopulation and economic decline. Limited public transportation and the opening of new expressways will influence residents to increasingly use private cars, increasing costs and carbon emissions. The lack of public transportation options will also make access to employment more difficult, especially for the most vulnerable populations, such as the elderly and people with reduced mobility. If the quadrilateral's infrastructure is completed, as well as the Marche 2032 Plan, there is a good chance that the regional market will become more competitive, with the possibility of attracting new investment and expanding existing businesses. Such expansion must be monitored, ensuring that it does not exacerbate land consumption and that industrial areas are not polluting.

Smart

If the Camerino region and the Cratere Maceratese do not adopt a plan for the implementation and expansion of smart technologies, the region will remain technologically backward compared to other more developed urban areas, which will significantly limit its potential for economic and social growth. The lack of smart technologies, such as real-time monitoring sensors, advanced communication networks and integrated urban management systems, will continue to hamper the efficiency of public services and crisis response (Pierantoni et al., 2022). Communication infrastructure, which is essential for the operation of smart technologies, will remain inadequate, especially in rural and mountainous areas where connectivity is already limited. Without investments in high-speed networks and Internet of Things (IoT) technologies, the region will not be able to implement effective intelligent transportation, energy management or environmental monitoring systems. This will result in less efficient urban management and greater vulnerability to crises such as natural disasters and infrastructure failures (*Pierantoni et al., 2019*). In addition, the lack of adoption of smart technologies in local industries and public services will limit the region's competitiveness and its ability to attract new investment. Companies that rely on advanced technologies to optimize their operations may avoid investing in the region, preferring areas where these infrastructures are already in place. This will contribute to economic stagnation and the continued migration of young people and qualified professionals to other regions with better technological opportunities.

The lack of smart technologies will negatively impact the local economy, reducing the efficiency of public services and increasing operating costs for companies. Without the adoption of advanced technologies, the region will struggle to compete in an increasingly digitized global market, which will limit economic growth and job creation. In addition, the lack of technological innovation will prevent the modernization of traditional sectors such as agriculture and industry, which are essential to the regional economy (Pierantoni et al., 2022). Socially, the absence of smart technologies will exacerbate digital inequalities and limit the population's access to modern and efficient services. Rural and isolated communities, which already face connectivity challenges, will become even more excluded from the benefits of the digital age, such as online education, telemedicine and digital public services. This could increase social isolation and reduce the quality of life of residents, especially those who are less able to adapt to technological changes (Pierantoni et al., 2019).

Without the adoption of smart technologies, the Camerino region and the Cratere Maceratese will continue to face significant challenges in terms of urban efficiency, economic growth and social inclusion. Technological modernization is essential to ensure that the region can develop sustainably and competitively on the global stage. In the long term, the implementation of smart technologies will be crucial to improving urban management, increasing resilience to crises and promoting innovation in all economic sectors.

Trade and Industry

If no intervention is carried out to revitalize the trade and industry sectors in Camerino and the Cratere Maceratese region, these sectors, already weakened by the 2016 earthquake, will continue to decline. The lack of innovation, modernization and economic support will result in prolonged stagnation, with serious economic consequences for the region. The destruction of industrial and commercial infrastructure, combined with the lack of investment in recovery, will leave many companies unable to resume operations or compete on the global market (Pierantoni et al., 2022). The inability to modernize local industry means that many companies will continue to use outdated technologies and practices, which limits their productivity and competitiveness. Without access to financial resources to invest in new technologies or expand their operations, these companies will be at a disadvantage compared to competitors from other, more developed regions. This could lead to factory closures and job losses, exacerbating unemployment and the exodus of young people in search of better opportunities (Pierantoni et al., 2019).

Local commerce will also be severely impacted. The lack of revitalization of commercial areas and the drop in residents' purchasing power will reduce demand for goods and services, resulting in the closure of stores and the degradation of shopping centers. Without a clear strategy to reactivate trade and attract new businesses, the region's urban and rural areas will continue to suffer from a loss of economic activity and rising unemployment.

The continued decline of trade and industry will have a devastating economic impact on the region. The loss of jobs in the industrial sector and the reduction in commercial activity will limit employment opportunities, resulting in greater dependence on social programs and a reduction in quality of life. In addition, the lack of economic dynamism will make it difficult to attract new investment, perpetuating a cycle of stagnation and decline (Pierantoni et al., 2022).

Socially, the decline of these sectors will exacerbate economic inequality and depopulation. Communities that depend on local industry for their livelihoods will face increasing economic hardship, which could lead to increased poverty and an exodus of young people and skilled workers to other regions. The loss of economic vitality will also impact social cohesion, as opportunities for community interaction and growth diminish (Pierantoni et al., 2019).

Without intervention, the future of commerce and industry in Camerino and the Cratere Maceratese region will be one of continued stagnation and decline. The lack of modernization, innovation and financial support will result in a significant economic weakening, which will have profound impacts on the quality of life of residents and the sustainability of the region. The revitalization of these sectors is essential to ensure the economic and social recovery of the region and to create an environment conducive to sustainable development.

Housing

If no significant action is taken to speed up the reconstruction and modernization of the housing sector in Camerino and the Cratere Maceratese region, the future scenario will be marked by a prolonged housing crisis and an increase in social inequalities. The destruction caused by the 2016 earthquake resulted in the loss of thousands of homes, many of which have yet to be rebuilt or adequately repaired. The lack of adequate funding, combined with slow and complex bureaucratic processes, will continue to impede progress in housing recovery (Pierantoni et al., 2022). The existing housing stock, which was already old and largely inadequate to meet modern standards of seismic safety and energy efficiency, will remain vulnerable to future natural disasters. Without retrofit and modernization programs, many dwellings will continue to offer poor living conditions, which will negatively impact the health and well-being of residents. In addition, the lack of new construction and affordable housing will exacerbate the housing shortage, making it even more difficult for low-income families to find safe and affordable housing (Pierantoni et al., 2019). The absence of an integrated urban planning strategy will also result in disordered housing development, which will not consider the long-term needs of the population or the principles of sustainability and resilience. Building new housing in unsuitable areas or without access to basic infrastructure and essential services can lead to the creation of marginalized neighborhoods and increase social and economic disparities in the region.

The lack of adequate and affordable housing will have significant economic impacts, limiting the region's ability to attract and retain residents and workers. The housing shortage will result in high rent and property prices, which will make it difficult for low- and middle-income families to afford housing. This could lead to increased poverty and social exclusion, especially in urban areas where the demand for housing is greatest (Pierantoni et al., 2022). Socially, the housing crisis will exacerbate depopulation and social isolation as more people, especially young people, seek better opportunities in other regions. The lack of safe and affordable housing can also negatively impact residents' mental and physical health, increasing the incidence of problems related to stress, housing insecurity and lack of access to basic services (Pierantoni et al., 2019).

Without intervention, the housing sector in Camerino and the Cratere Maceratese region will continue to face significant challenges, which will compromise sustainable development and the quality of life of residents. The modernization and expansion of the housing stock, together with the implementation of an integrated urban planning strategy, are essential to ensure that the region can offer safe, affordable and resilient housing for all its inhabitants.

Agricolture

If no action is taken to revitalize and modernize the agricultural sector in Camerino and the Cratere Maceratese region, the future of this sector will be marked by continued decline, with serious consequences for the rural economy and environmental sustainability. Agriculture, which is a vital part of the local economy and regional culture, is already facing significant challenges due to a lack of innovation, environmental degradation and demographic change. Without interventions to support farmers and modernize agricultural practices, these challenges will intensify (Pierantoni et al., 2022). Lack of access to finance, technology and technical support will continue to prevent farmers from adopting more efficient and sustainable practices. As a result, agricultural productivity will remain low, and production costs will continue to rise, making farming less economically viable. This could lead to the abandonment of farmland and the conversion of productive areas into uncultivated land, exacerbating environmental degradation and the loss of biodiversity (Pierantoni et al., 2019). In addition, agricultural infrastructure, including irrigation systems, storage and transportation, will remain inadequate, limiting farmers' ability to compete in the market. The lack of modern and efficient irrigation systems, for example, will result in unsustainable water use, exacerbating the problems of water scarcity and soil degradation. Without investment in infrastructure and advanced agricultural technologies, the region will not be able to increase its productivity or improve the quality of its agricultural products.

The continued decline of agriculture will have significant economic impacts, resulting in job losses and lower incomes for rural families. The lack of economic opportunities in the agricultural sector will increase the rural exodus, contributing to the depopulation of rural areas and the ageing of the population. This could lead to the collapse of entire communities as young people migrate to urban areas in search of better opportunities (v). Socially, the decline of agriculture will impact social cohesion and the continuity of cultural traditions associated with rural life. The loss of traditional agricultural practices and knowledge passed down from generation to generation will result in an erosion of the region's intangible cultural heritage. In addition, the decline in agricultural production could affect local food security, increasing dependence on imported food and reducing the region's self-sufficiency (Pierantoni et al., 2019).

Without intervention, the agricultural sector in Camerino and the Cratere Maceratese region will face a future of continued decline, with devastating economic, social and environmental impacts. The revitalization of agriculture, through investments in infrastructure, technologies and support for farmers, is essential to ensure the sustainability and resilience of the rural economy. In the long term, the modernization of the agricultural sector and the promotion of sustainable practices will be crucial for sustainable development and the preservation of rural culture in the region.

4.4.3 Evaluation Model

The data used to build the Evaluation Model was made available to the participants and is listed in Appendix B.

Cultural Heritage

The cultural assets of Camerino and the Cratere Maceratese region represent invaluable wealth for the cultural identity, tourism and economic development of the region. However, the analysis of future scenarios without intervention, as outlined in the Process Model, reveals that continued inertia will result in the irreversible loss of these assets, with devastating consequences for social cohesion and tourism. The need for intervention is urgent, and actions must be directed towards the restoration, preservation and promotion of these cultural assets (Pierantoni et al., 2022).

Proposals for improvement:

1. **Restoration and preventive conservation:** The first and most urgent measure is to implement a comprehensive restoration program for damaged cultural assets. This includes not only the physical reconstruction of monuments and historic buildings, but also the application of preventive conservation techniques to avoid future damage. Funding for these projects can be obtained through public-private partnerships, as well as from European funds dedicated to the preservation of cultural heritage (Pierantoni et al., 2019). It is crucial that these interventions respect traditional building methods and use authentic materials to preserve the historical integrity of the structures.

2. **Creation of integrated cultural routes:** To revitalize tourism and promote cultural assets, it is recommended to create integrated cultural routes that connect different monuments and places of interest in the region. These routes can be themed, for example, around historical figures or significant events, and should include partnerships with local businesses to offer complete tourist packages. The promotion of these routes can be intensified through digital marketing campaigns and partnerships with national and international tourism agencies (Pierantoni et al., 2022).
3. **Education and community involvement:** The long-term sustainability of preservation projects depends on the involvement of the local community. Education and awareness programs about the importance of cultural heritage can be implemented in schools and communities, fostering a sense of belonging and responsibility among residents. In addition, workshops and training courses in traditional restoration techniques can train the local population, creating jobs and promoting direct engagement in the conservation process (Pierantoni et al., 2019).
4. **Use of Digital Technologies for Preservation:** The digitization of cultural heritage, through technologies such as photogrammetry and 3D modeling, can be a powerful tool for the preservation and promotion of these assets. These technologies allow for the creation of digital replicas that can be used for educational and tourist purposes, as well as serving as accurate records for future restorations. In addition, the creation of virtual tours can attract tourists who, for different reasons, cannot physically visit the sites.
5. **Integrated management of cultural heritage:** The creation of a regional body or consortium dedicated to the integrated management of cultural assets could improve the coordination and effectiveness of preservation actions. This body would be responsible for administering funds, overseeing restoration projects and promoting cultural heritage. Integrated management allows for a more strategic and coordinated approach, ensuring that resources are used effectively and that interventions are sustainable in the long term (Pierantoni et al., 2022).

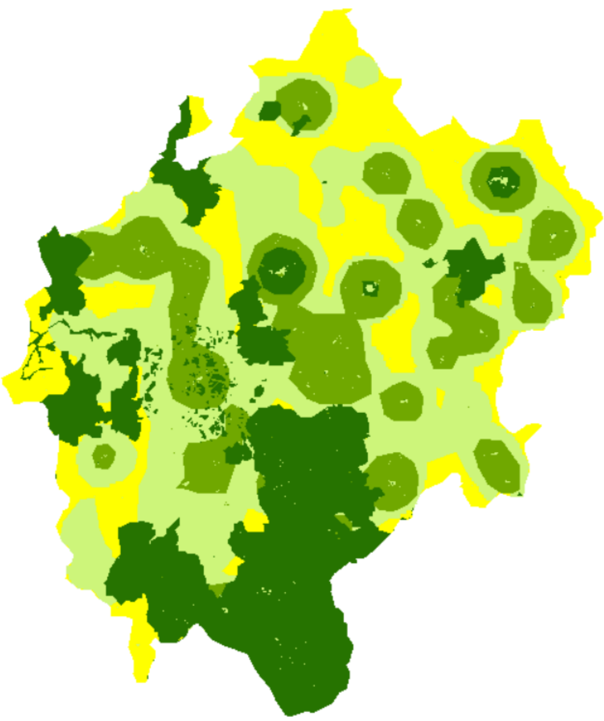


Figure 57: Evaluation Model - Cultural Heritage
Source: Author

Conclusion:

The preservation and revitalization of cultural assets in Camerino and the Cratere Maceratese region are fundamental to the economic, social and cultural recovery of the area. The improvement proposals suggested here offer a way forward to protect this priceless heritage, ensuring that it continues to play a central role in the region's identity and the development of tourism. Implementing these actions will require coordination, investment and the active engagement of all stakeholders, but the long-term benefits will be significant (Pierantoni et al., 2019).

Tourism

Tourism in Camerino and the Cratere Maceratese region has enormous potential for economic revitalization, especially in a post-disaster scenario. However, the decline in tourism observed after the 2016 earthquake, as discussed in the Process Model, points to the need for strategic interventions to revitalize the sector. The current state of tourism infrastructure and the deterioration of cultural assets represent significant challenges, but also opportunities for innovation and the sustainable development of tourism (Pierantoni et al., 2022).

Proposals for improvement:

1. **Upgrading tourist infrastructure:** The revitalization of tourism begins with the upgrading of tourist infrastructure, including hotels, restaurants and other support facilities. Investments in modernizing and improving these facilities are essential to ensure that tourists have a comfortable and attractive experience. This also includes restoring damaged areas and building new attractions, such as interpretation centers and museums, which can enhance the region's cultural and natural heritage (Pierantoni et al., 2019).
2. **Development of rural tourism and ecotourism:** Rural tourism and ecotourism offer a unique opportunity to diversify the tourism offer and attract new audiences. The promotion of ecological trails, visits to organic farms and authentic experiences of rural life can attract tourists in search of experiences that are more connected to nature and local culture. To do this, it is necessary to invest in improving the infrastructure for access to rural areas and in training local guides who are qualified to lead these activities.
3. **Integration of intelligent technologies in tourism:** The adoption of smart technologies can transform the tourist experience and improve the management of the sector. Mobile applications offering information on cultural routes, online reservations and feedback systems can facilitate planning and visitation. In addition, the use of augmented reality technologies can enrich the visitor experience, allowing them to visualize virtual reconstructions of historical monuments or explore hard-to-reach areas in an immersive way (Pierantoni et al., 2022).
4. **Public-private partnerships for tourism promotion:** Effective tourism promotion requires collaboration between the public and private sectors. Partnerships involving tourism agencies, local governments and private companies can create more effective and coordinated marketing campaigns aimed at both the domestic and international markets. Promotion should highlight not only cultural heritage, but also sustainable tourism opportunities and the authentic experiences the region can offer (Pierantoni et al., 2019).
5. **Development of a Sustainable Tourism Strategic Plan:** A strategic plan for sustainable tourism should be developed to guide the sector's growth in the coming years. This plan should include clear guidelines on environmental preservation, economic sustainability and cultural promotion. Sustainable tourism not only helps to protect natural and cultural resources, but also ensures that the economic benefits of tourism are distributed equitably among the local population.

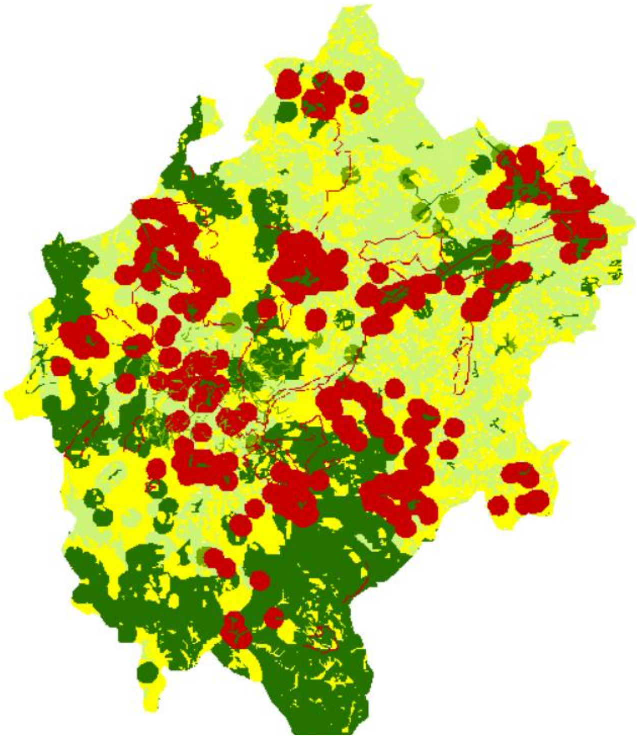


Figure 58: Evaluation Model: Tourism
Source: Author

Conclusion:

Revitalizing tourism in Camerino and the Cratere Maceratese region is essential for economic recovery and for strengthening the region's cultural identity. The proposals put forward offer a way to turn tourism into an engine of sustainable development, integrating innovation, preservation and community participation. Implementing these measures will require a coordinated effort between all stakeholders, but the potential for positive impact fully justifies the investment (Pierantoni et al., 2022).

Energy

The energy infrastructure in Camerino and the Cratere Maceratese region presents significant challenges, especially after the damage caused by the 2016 earthquake. The analysis in the Process Model highlighted the urgent need to modernize and diversify energy sources to ensure the region's resilience and sustainability. The current state of the energy system, characterized by an over-reliance on conventional sources and an aging infrastructure, is unsustainable in the long term and poses a significant risk to the region's economic and social development (Pierantoni et al., 2022).

Proposals for improvement:

1. **Modernization of the electricity grid:** Modernizing the electricity grid is a priority for improving the region's energy resilience. This includes replacing obsolete infrastructure, implementing smart grid technologies and installing smart meters to better manage energy consumption. Modernization will not only reduce energy losses, but also improve the grid's ability to integrate renewable energy sources (Pierantoni et al., 2019).
2. **Expansion of renewable energies:** The diversification of energy sources, with a special focus on renewable energies, is essential for long-term energy sustainability. Investments in solar, wind and biomass energy can reduce dependence on fossil fuels and increase the region's energy self-sufficiency. The creation of tax incentives and subsidies for the installation of solar panels in homes and businesses can accelerate this transition, also contributing to the reduction of carbon.
3. **Promoting energy efficiency:** Implementing energy efficiency programs, especially in public and residential buildings, is crucial to reducing energy consumption and the associated costs. This includes retrofitting existing buildings to improve thermal insulation, replacing old heating systems with more efficient solutions and promoting the use of energy-saving appliances. In addition, awareness campaigns can educate the population about more sustainable energy consumption practices (Pierantoni et al., 2022).
4. **Development of support infrastructures for electric vehicles:** The transition to more sustainable mobility requires the creation of a suitable infrastructure to support electric vehicles. This includes installing charging stations in strategic locations such as city centers,

shopping areas and tourist attractions. Encouraging the adoption of electric vehicles through subsidies and tax incentives can also contribute to reducing carbon emissions and improving air quality (Pierantoni et al., 2019).

5. **Strengthening energy resilience:** To ensure the resilience of the energy system in the face of natural disasters and other crises, it is necessary to develop decentralized energy solutions, such as micro-grids and energy storage systems. These solutions allow isolated communities or rural areas to maintain their energy supply during interruptions to the main grid. Promoting off-grid energy systems can also benefit remote areas that currently face difficulties accessing a stable electricity grid.

Conclusion:

The modernization of the energy infrastructure and the promotion of renewable sources are essential to ensure the sustainability and resilience of the Camerino region and the Cratere Maceratese. The proposals presented here offer a clear path to transforming the region's energy system, integrating innovation, efficiency and sustainability. Implementing these measures will strengthen the region's ability to face future crises and promote sustainable economic development (Pierantoni et al., 2022).

Green Infrastructure

Green infrastructure in Camerino and the Cratere Maceratese region plays a vital role in promoting environmental sustainability and quality of life for residents. As discussed in the Process Model, the continued deterioration of these areas without intervention will result in serious environmental, economic and social problems. The preservation and revitalization of green infrastructure is essential to mitigate the impacts of climate change, promote biodiversity and improve the well-being of the local population (Pierantoni et al., 2022).

Proposals for improvement:

1. **Reforestation and recovery of degraded areas:** One of the most important steps to improve green infrastructure is the implementation of reforestation and recovery programs for degraded areas. This includes planting native species in areas affected by deforestation or erosion, creating ecological corridors to promote connectivity between natural areas and restoring critical habitats. These actions will not only improve environmental quality, but will also increase the region's resilience to natural disasters such as landslides and floods (Pierantoni et al., 2019).
2. **Development of urban green infrastructure:** The creation and maintenance of urban green spaces, such as parks, gardens and squares, are essential for improving the quality of life in the region's cities and towns. These spaces offer multiple benefits, including improving the mental and physical health of residents, mitigating urban heat islands and promoting social cohesion. The incorporation of nature-based solutions, such as green roofs and vegetated walls, can also contribute to the energy efficiency of buildings and the management of rainwater.
3. **Promotion of ecotourism and nature tourism:** Green infrastructure can also be an engine for economic development by promoting ecotourism and nature tourism. Well-managed nature trails, camping areas and natural parks can attract tourists interested in outdoor experiences and environmental conservation. To do this, it is necessary to invest in the creation of adequate infrastructure, such as signposting, visitor centers and environmental education programs that promote the conservation and sustainable use of natural resources (Pierantoni et al., 2022).
4. **Environmental education and community involvement:** The long-term sustainability of green infrastructure depends on community engagement and awareness. Environmental education programs in schools, workshops for adults and public awareness campaigns can

foster a sense of collective responsibility for preserving green spaces. In addition, volunteer initiatives for the maintenance and improvement of parks and natural areas can strengthen the community's bond with the local environment and promote active participation in the management of these spaces (Pierantoni et al., 2019).

5. **Integrating green infrastructure into urban and rural planning:** Green infrastructure should be considered a central component in the region's urban and rural planning. This includes incorporating green spaces into new housing developments, protecting natural areas during the urbanization process and promoting sustainable agricultural practices that preserve native vegetation. Integrating green infrastructure into master plans and development policies will ensure that these areas are protected and valued as essential assets for the well-being of the population.

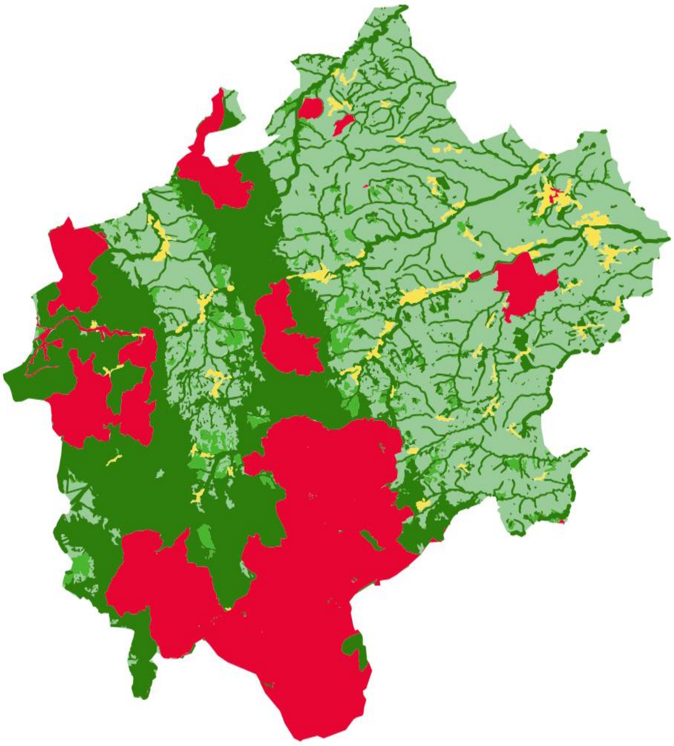


Figure 59: Evaluation model: Energy
Source: Author

Conclusion:

The preservation and revitalization of green infrastructure is key to ensuring sustainable and resilient development in Camerino and the Cratere Maceratese region. The proposals presented offer a clear path for integrating green infrastructure into regional planning, promoting environmental, social and economic benefits. In the long term, these actions will contribute to the region's resilience to climate change, the protection of biodiversity and the improvement of residents' quality of life (Pierantoni et al., 2022).

Blue Infrastructure

Blue infrastructure, which includes water management, drainage systems and sewage networks, is crucial for the environmental sustainability and resilience of the Camerino and Cratere Maceratese region. As highlighted in the Process Model, a lack of intervention to modernize and expand this infrastructure will result in serious risks to public health, agriculture and natural disaster management. The current assessment shows that the blue infrastructure is undersized and aging, in urgent need of improvement to meet current and future demands (Pierantoni et al., 2022).

Proposals for improvement:

1. **Modernization of drainage and sanitation systems:** Modernizing drainage and sanitation systems is essential to prevent flooding and improve water quality in the region. This includes building new sewage networks and upgrading existing ones, installing effective drainage systems in urban and rural areas and creating modern water treatment plants. These

improvements will not only reduce the risk of flooding but will also ensure that the water reaching communities is clean and safe for consumption (Pierantoni et al., 2019).

2. **Sustainable management of water resources:** In addition to water conservation practices and the construction of reservoirs, it is important to integrate water resource management into territorial planning, ensuring that agricultural, industrial and urban activities are carried out in a way that preserves watersheds and minimizes environmental impact. The creation of river basin committees can involve local communities in resource management, ensuring a participatory approach adapted to the specific needs of the region.
3. **Implementation of water treatment technologies:** The introduction of advanced water treatment technologies, such as biological filtration systems, membrane treatments and desalination, can improve the quality of water available for consumption and irrigation. In addition, upgrading sewage treatment plants with technologies that enable the recovery of nutrients and energy from waste can contribute to environmental sustainability and the circular economy in the region (Pierantoni et al., 2022).
4. **Prevention and mitigation of water-related disasters:** The Cratere Maceratese region, due to its mountainous geography, is particularly vulnerable to landslides and floods. Therefore, the construction of flood control infrastructure, such as dikes and canals, as well as the implementation of early warning systems, are crucial to protect local communities. In addition, restoring wetlands and rehabilitating natural waterways can help absorb excess water during storms and reduce the risk of disasters (Pierantoni et al., 2019).
5. **Promoting environmental education and awareness:** To ensure the long-term effectiveness of blue infrastructure interventions, it is essential to educate and raise awareness among the local population about the importance of conserving water resources. Educational programs in schools, public campaigns and community workshops can help promote sustainable water use practices and encourage community participation in water resource management. Raising awareness can also include encouraging the adoption of domestic water conservation technologies, such as low-flow taps and shower heads.

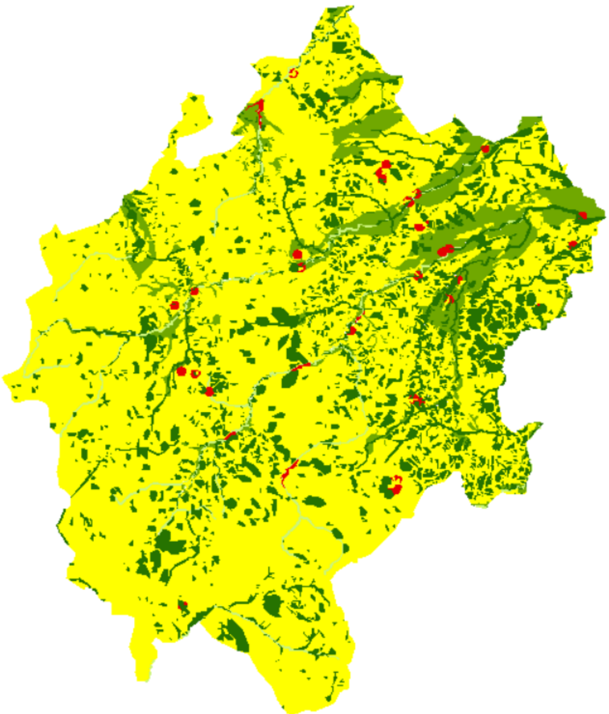


Figure 60: Evaluation Model: Blu Infrastructure
Source: Author

Conclusion:

The blue infrastructure in Camerino and the Cratere Maceratese region is an essential component for regional sustainability and resilience. The improvement proposals presented aim to modernize and expand this infrastructure, guaranteeing water security, environmental protection and preparedness for natural disasters. With integrated management and the active participation of the community, these measures can transform the region's blue infrastructure, ensuring a more sustainable and secure future for all its inhabitants (Pierantoni et al., 2022).

Transportation

Taking into account the representation and process models, the areas of greatest or least feasibility for the transport system are suggested, as well as listing some important proposals. The system includes projects for the realization of infrastructures, nodes and routes for fast mobility and soft mobility to support the flow of people and goods. The transport system in the Crater area is characterized by considerable slowness of movement and the difficulty of connecting municipalities to each other and on a supralocal scale. This situation is mainly attributed to a road network of old origin, influenced by morphological difficulties and the widespread fragmentation of urban settlements. The low density of these settlements results in long distances to be covered and high costs for the implementation of public collective mobility systems. In addition, there is a complexity and slowness in accessing essential service centers, largely resulting from the lack of connection between various modes of public transport and private transport routes, a problem further exacerbated by the damage caused by the earthquake.

Some suggested actions are:

- Support intermodality, connecting ports, airports, railway stations and highways with each other and with local transport (at municipal, regional, national and international level) for public and private transport;
- Strengthen public passenger transport by introducing multimodal nodes that connect each municipality to each other and to the centers of services and tourist activities;
- Strengthen strategically important infrastructures, improving slow and fast connections and facilitating the connection between rail lines and public transport.
- Complete the bicycle system;
- Ecologically sustainable tourism routes;
- Encourage the use of clean energy vehicles;
- Strengthen transportation infrastructure against the possibility of a natural event (earthquakes, landslides and floods) inside and outside built-up areas;
- Rehabilitate infrastructure damaged by the earthquake.

Thus, the evaluation model starts from the representation model, to understand the existing infrastructure of roads (national, regional, provincial, local), railroads, cycle paths, public transport and trails, ports and airports. From this study, we started by considering the slope of the terrain (maximum 10%) and the risk characteristics, demarcating and excluding areas at risk of flooding and landslides, wetlands and near water bodies. Protected natural areas and prestigious crops were also indicated, protecting these areas from major interventions. Urban and industrial areas were less suited to the proposals, indicating that the preference for intervention is in extra-urban connections.

Proposals for improvement:

1. **Reconstruction and modernization of road infrastructure:** The reconstruction of roads and bridges damaged by the earthquake is a priority to re-establish connectivity in the region. In addition, the modernization of existing roads, including the widening of lanes and the implementation of safety measures such as guard rails and adequate signage, is essential to improve mobility and reduce the risk of accidents. The use of sustainable construction materials and modern engineering techniques can extend the life of these infrastructures and increase their resilience to natural disasters (Pierantoni et al., 2019).
2. **Expansion of public transport:** The expansion and improvement of public transport services are key to reducing dependence on private vehicles and improving accessibility, especially for vulnerable populations. This includes introducing new bus routes, modernizing the existing fleet with more efficient vehicles and creating integrated transport systems that connect rural and urban areas. Subsidies and incentives can be offered to encourage the

use of public transport, contributing to the reduction of carbon emissions and the improvement of air quality.

3. **Development of infrastructure for sustainable mobility:** Promoting forms of sustainable mobility, such as cycle paths, pedestrian routes and infrastructure for electric vehicles, is essential to creating a greener and more accessible transportation system. The construction of safe and well-connected cycle paths can encourage the use of bicycles as a means of daily transportation, while the installation of charging stations for electric vehicles can support the transition to a more sustainable vehicle fleet (Pierantoni et al., 2022).
4. **Integration of intelligent technologies in transportation:** The application of intelligent technologies in transport management can optimize traffic flow, reduce congestion and improve road safety. This includes the use of traffic sensors, real-time monitoring systems and mobile applications that provide up-to-date information on traffic and transportation options. The implementation of electronic ticketing systems for public transport can also facilitate the use of services and improve the user experience (Pierantoni et al., 2019).
5. **Integrated transport planning:** The creation of an integrated transportation plan that aligns mobility needs with urban and rural development objectives is fundamental to the efficiency of the transportation system. This plan must take into account population growth, changes in transportation demands and the need for environmental preservation. Collaboration between municipalities, regional government and private actors will be crucial to the success of this integrated approach.

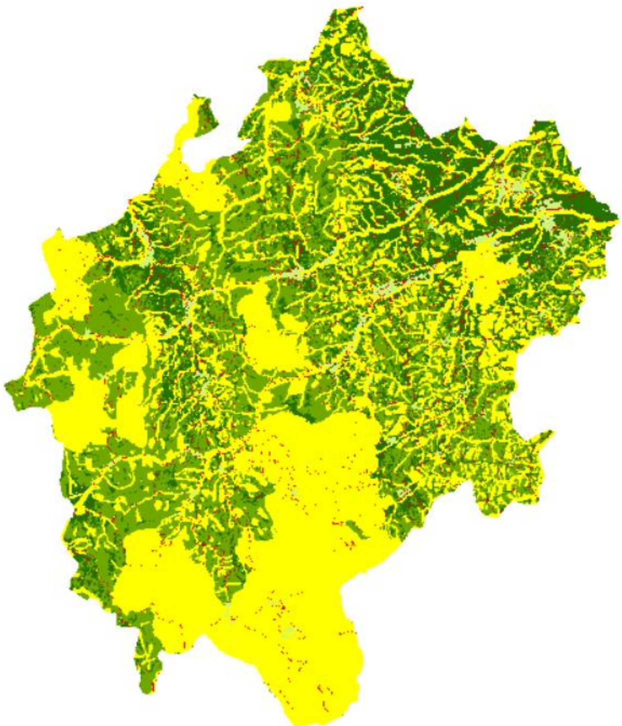


Figure 61: Evaluation Model: Transportation

Source: Author

Conclusion:

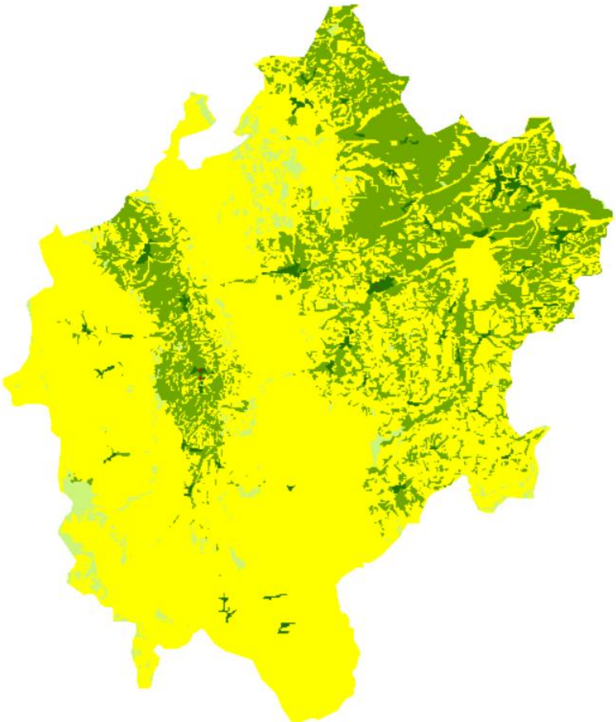
The modernization and expansion of transport infrastructure is essential to ensure connectivity, economic development and sustainability in Camerino and the Cratere Maceratese region. The improvement proposals outlined here aim to create a resilient, safe and sustainable transportation system that meets the needs of the population and promotes regional integration. Implementing these measures will require significant investment and a coordinated effort, but the long-term benefits for mobility and quality of life fully justify the investment (Pierantoni et al., 2022).

Smart

The adoption of smart technologies in Camerino and the Cratere Maceratese region has the potential to transform urban management, improve the efficiency of public services and boost economic development. The Process Model analysis indicated that, without interventions, the region will remain technologically outdated, which will limit its growth opportunities. The implementation of intelligent solutions is therefore essential to ensure that the region remains competitive and able to respond to the demands of the future (Pierantoni et al., 2022).

Proposals for improvement:

1. **Development of communication infrastructure:** A base para qualquer iniciativa de cidade inteligente é uma infraestrutura de comunicação robust, including high-speed networks and broad internet coverage. Investing in broadband expansion and the installation of 5G networks is crucial to support technologies such as the Internet of Things (IoT), which can optimize urban management. Ensuring connectivity in rural and mountainous areas is also essential to promote digital inclusion and enable all residents to benefit from smart technologies (Pierantoni et al., 2019).
2. **Implementation of intelligent urban management systems:** The adoption of smart urban management systems, such as traffic monitoring, waste management and energy efficiency platforms, can significantly improve the efficiency of public services. For example, connected waste sensors can optimize collection routes, reducing costs and emissions, while intelligent street lighting systems can adjust lighting based on the presence of pedestrians, saving energy.
3. **Development of intelligent solutions for the agricultural sector:** The agricultural sector, which is essential to the region's economy, can benefit enormously from the application of smart technologies. Solutions such as remote crop monitoring, automated irrigation and the use of drones for soil analysis can increase efficiency, reduce costs and improve the sustainability of agricultural practices. Promoting precision agriculture can help farmers maximize production and minimize the use of inputs such as water and fertilizers (Pierantoni et al., 2022).
4. **Creation of innovation spaces and start-ups:** Stimulating technological innovation through the creation of start-up incubators and accelerators can attract talent and investment to the region. These innovation spaces can focus on solutions to local challenges, such as natural disaster management, energy efficiency and sustainable agriculture. Partnerships between universities, government and the private sector will be essential to create a robust innovation ecosystem (Pierantoni et al., 2019).
5. **Digital education and training:** The successful adoption of smart technologies also depends on empowering the population. Digital literacy programs and training in new technologies must be implemented to ensure that all residents, regardless of age or location, can fully participate in the digital transformation. This includes everything from basic education in communication technologies to specific training in the use of smart tools in agriculture and urban management.



Conclusion:

The adoption of smart technologies is a strategic opportunity to transform Camerino and the Cratere Maceratese region into an innovative, efficient and competitive area. The proposals put forward offer a way to modernize urban management, promote sustainability and stimulate economic development. Implementing these measures will require investments in infrastructure, innovation and education, but the benefits for the region's quality of life and resilience will be substantial (Pierantoni et al., 2022).

Figure 62: Evaluation Model: SMART
Source: Author

Trade and Industry

The trade and industry sectors in Camerino and the Cratere Maceratese region face significant challenges, especially following the impacts of the 2016 earthquake and subsequent economic crises. As discussed in the Process Model, the lack of modernization and innovation in these sectors has limited economic growth and job creation. Revitalizing trade and industry is crucial for the region's economic recovery and for promoting sustainable development (Pierantoni et al., 2022).

Proposals for improvement:

1. **Modernization of industrial infrastructures:** Modernizing industrial infrastructure is essential to increasing the competitiveness of local companies. This includes renovating manufacturing facilities, updating equipment and adopting advanced production technologies such as automation and robotics. Investing in logistics infrastructure, such as warehouses and distribution centers, is also key to improving the efficiency of supply chains and reducing operating costs (Pierantoni et al., 2019).
2. **Incentives for innovation and research & development:** To stimulate innovation and the growth of local industry, it is necessary to create incentives for investment in research and development (R&D). This can include subsidies, tax credits and partnerships with universities and research centers to develop new technologies and products. The promotion of industrial clusters, where companies collaborate on innovation and share resources, can strengthen the region's ability to compete in global markets.
3. **Revitalization of shopping centers:** Revitalizing urban and rural shopping centers can help attract consumers and boost local commerce. This includes renovating public spaces, modernizing store fronts and promoting events and fairs that encourage visitation and consumption. The creation of specialized trade zones, where themed stores and local product markets can thrive, can differentiate the region and attract tourists and residents alike (Pierantoni et al., 2022).

4. **Promoting e-commerce:** E-commerce offers a significant opportunity to expand the reach of local businesses beyond regional borders. Training programs for local traders in online sales, digital marketing and e-commerce logistics can help integrate small and medium-sized businesses into the global market. In addition, the creation of regional digital platforms that aggregate local products can facilitate direct sales to consumers and reduce dependence on intermediaries (Pierantoni et al., 2019).
5. **Encouraging entrepreneurship and start-ups:** Encouraging entrepreneurship and the creation of startups can revitalize the commercial and industrial sector, bringing new ideas and business models to the region. Entrepreneurial support programs, including mentoring, access to financing and coworking spaces, can help new businesses establish themselves and grow. The promotion of business incubators, focused on strategic sectors such as technology and sustainability, can attract talent and investment.

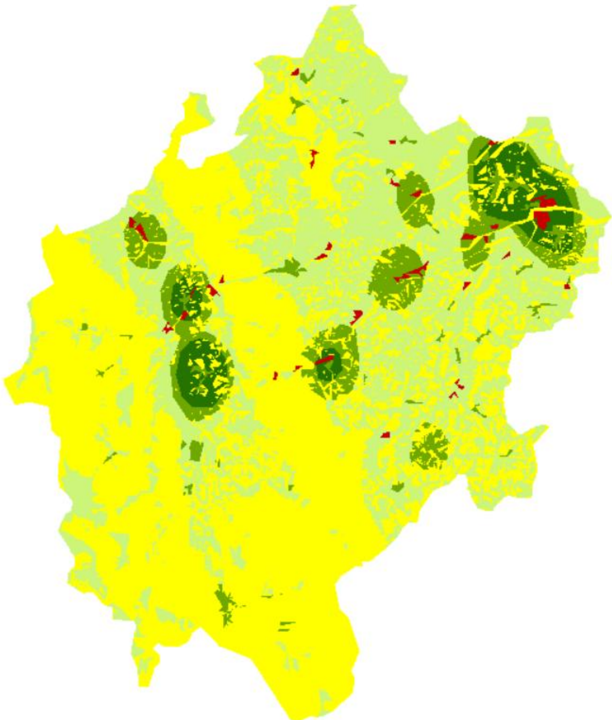


Figure 63: Evaluation Model: Trade and Industry
Source: Autor

Conclusion:

The revitalization of the trade and industry sectors is essential for the economic recovery of Camerino and the Cratere Maceratese region. The proposals outlined here offer a way to modernize infrastructure, encourage innovation and create an environment conducive to sustainable economic growth. Implementing these measures will require coordinated efforts between the public and private sectors and the local community, but the benefits for the regional economy and quality of life will be significant (Pierantoni et al., 2022).

Housing

As analyzed in the Process Model, the lack of safe and affordable housing, combined with the slow pace of reconstruction, is exacerbating the housing crisis in the region. Modernizing the housing sector is crucial not only to improve the quality of life of residents, but also to promote social cohesion and sustainable development (Pierantoni et al., 2022).

The proposals submitted must be able to stimulate territorial regeneration processes in urban, peri-urban or peripheral areas, integrating them with initiatives to enhance historical and cultural heritage. The process must obviously be in line with modern standards and techniques for post-earthquake reconstruction, also taking into account the best option in terms of energy efficiency from renewable sources for each region. Post-earthquake reconstruction must consider innovative approaches and new development paths for local communities, to avoid the risk of having rebuilt factories and destroyed communities at the end of the process. Future strategies should prioritize facilitating and accelerating the reconstruction process, as seven years after the last earthquake, some sites are still at an early stage. Exploring new uses for physical infrastructure can be a beneficial approach, especially to curb the processes of abandonment and degradation, particularly of assets with identity value. Consideration of environmental quality and sustainability must be paramount, ensuring that reconstruction focuses on the well-being of the population, both environmentally and in the design and organization of spaces, expanding the supply of accessible public spaces for recreation and leisure activities. The post-disaster phase must also consider the feasibility of a permanent digital transition, guaranteeing access to ultra-broadband for all residents and improving public services. Connectivity can create new job opportunities and make it easier to adapt to digital activities in emergency situations, as has been demonstrated during the Covid-19 pandemic. In addition, digitalization can promote greater access and efficiency in public and essential services, such as medical, cultural and educational reserves. To mitigate the risk of digital exclusion, especially among the elderly and those living in rural areas, targeted training courses can be implemented, potentially generating new jobs.

Proposals for improvement:

1. **Speeding up the reconstruction of damaged homes:** Speeding up the reconstruction processes is essential in order to provide safe housing for families displaced by the earthquake. This can be achieved by simplifying bureaucratic procedures, allocating more financial resources and using modern construction technologies that allow for faster and more resilient construction. Reconstruction must also consider seismic safety standards and energy efficiency, ensuring that new housing is better prepared to face future disasters (Pierantoni et al., 2019).
2. **Implementation of retrofit and modernization programs:** In addition to reconstruction, it is essential to modernize the existing housing stock to meet modern standards of comfort, safety and sustainability. Retrofit programs that improve thermal insulation, replace inefficient heating systems and install renewable energy technologies can reduce energy consumption and improve residents' quality of life. Tax incentives and subsidies can be offered to support families in making these improvements.
3. **Expansion of affordable housing:** The shortage of affordable housing is a critical problem in the region. To tackle it, it is necessary to invest in the construction of new affordable housing units, especially for low- and middle-income families. Public-private partnerships can be established to finance the construction of social housing, while unused public land can be made available for affordable housing projects. Implementing rent control policies and promoting housing cooperatives can also help make housing more affordable for everyone (Pierantoni et al., 2022).
4. **Sustainable urban planning:** Creating an urban development plan that integrates housing, green infrastructure, transportation and public services is essential to ensure long-term sustainability. New housing developments should be designed to be compact and efficient in terms of land use, with easy access to public transportation and essential services. In addition, planning should incorporate nature-based solutions, such as parks and green spaces, to promote residents' well-being and environmental sustainability (Pierantoni et al., 2019).
5. **Promoting community participation initiatives:** Involving the local community in the housing planning and reconstruction process can ensure that the solutions developed meet the real needs of residents. Workshops, public consultations and participatory design programs can help create a sense of ownership and responsibility among residents, promoting social cohesion and community resilience. In addition, assisted self-build initiatives can allow families to actively participate in the construction of their own homes, reducing costs and strengthening the bond with the community.

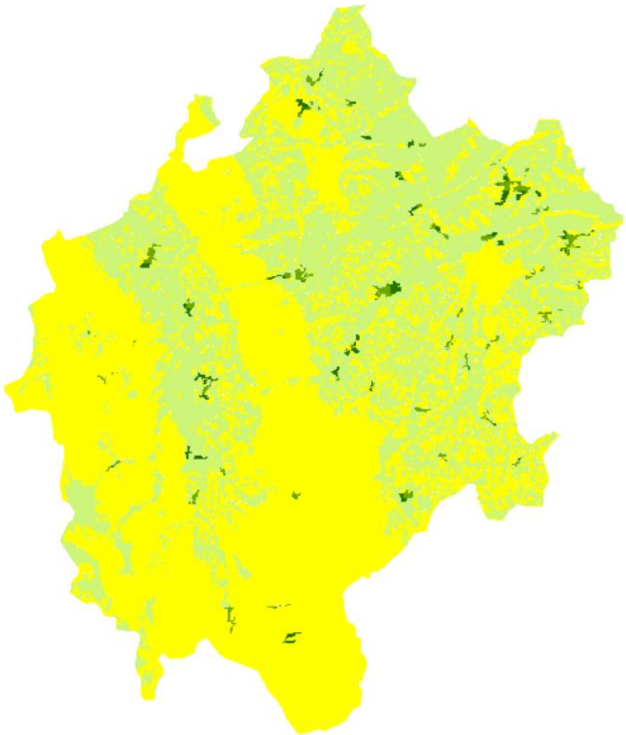


Figure 64: Evaluation Model: Housing

Conclusion:

Modernizing the housing sector is fundamental to the recovery and sustainable development of Camerino and the Cratere Maceratese region. The improvement proposals put forward aim to speed up reconstruction, improve the quality of housing and ensure that all residents have access to safe and affordable housing. Implementing these measures will require coordination between the government, the private sector and the community, but the benefits in terms of quality of life, social cohesion and sustainability fully justify the

Agricolture

The agricultural sector in Camerino and the Cratere Maceratese region is a crucial component of the local economy, but faces significant challenges, such as a lack of innovation, environmental degradation and the impact of rural depopulation. As discussed in the Process Model, without interventions, agriculture in the region will continue to decline, resulting in economic losses and the erosion of rural culture. The revitalization of the agricultural sector is essential to ensure economic sustainability and the preservation of the region's cultural heritage (Pierantoni et al., 2022).

Proposals for improvement:

1. **Innovation and agricultural modernization:** The modernization of agricultural practices is essential to increase productivity and sustainability in the sector. This includes the adoption of advanced agricultural technologies, such as drip irrigation systems, crop monitoring by drones and precision agriculture, which allow for more efficient management of resources and increase production. Promoting research and development into new crop varieties adapted to the local climate can also help improve crop resilience (Pierantoni et al., 2019).
2. **Incentives for sustainable agriculture:** Encouraging sustainable agricultural practices is crucial to preserving the environment and ensuring the long-term viability of the sector. Subsidy programs for conversion to organic farming, the use of biological inputs and the adoption of soil and water conservation practices can help reduce the environmental impact of agriculture. In addition, the promotion of agroforestry and integrated farming systems can increase biodiversity and improve the resilience of farms to climate.
3. **Development of local value chains:** Strengthening local value chains, from production to marketing, can increase farmers' incomes and promote the local economy. The creation of agricultural cooperatives that allow for the joint purchase of inputs and the direct sale of products can improve the competitiveness of small farmers. In addition, the development of regional brands that value local products, such as cheeses, wines and olive oils, can increase added value and attract consumers from wider markets (Pierantoni et al., 2022).
4. **Farmer education and training:** Investing in training farmers is essential for the adoption of new technologies and sustainable practices. Ongoing training programs, workshops and

technical courses can help farmers keep up to date with the best agricultural practices and use new management tools. The creation of agricultural demonstration and experimentation centers can also serve as reference points for innovation and the development of new techniques (Pierantoni et al., 2019).

5. **Promoting rural tourism and multifunctional agriculture:** Integrating agriculture with rural tourism and other economic activities can diversify farmers' sources of income and promote the sustainability of the sector. The creation of agritourisms, where tourists can experience rural life and consume local products, can generate new job opportunities and preserve rural cultural heritage. In addition, promoting events such as agricultural fairs and seasonal festivals can attract visitors and strengthen ties between the urban and rural communities.

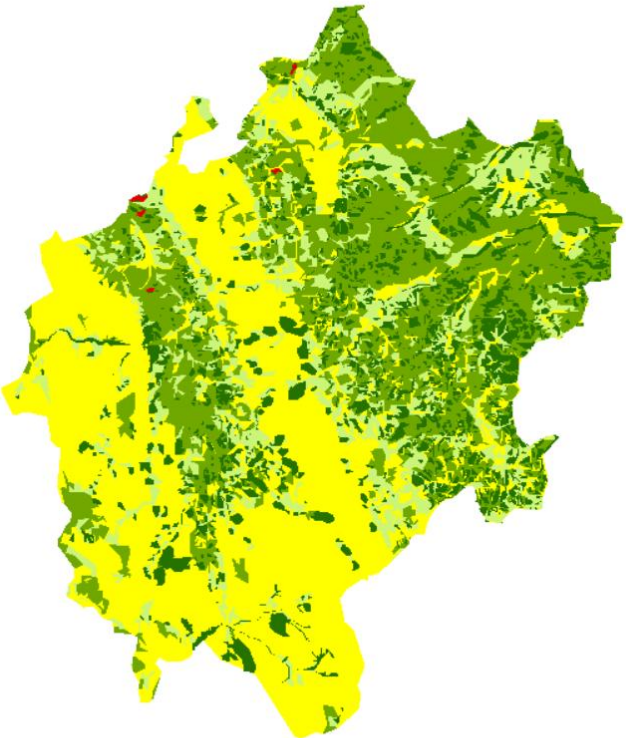


Figure 65: Evaluation Mondel: Agriculture.

Source: Author.

Conclusion:

The revitalization of agriculture in Camerino and the Cratere Maceratese region is essential for economic development, environmental sustainability and cultural preservation. The improvement proposals outlined aim to modernize the sector, promote sustainable practices and integrate agriculture with other economic activities. Implementing these measures will require government support, technological innovation and the active participation of farmers, but the benefits in terms of resilience, sustainability and quality of life will be significant (Pierantoni et al., 2022).

4.4.4 Change Model:

Dividing participants into systems

The second day of the workshop was dedicated exclusively to project proposals and negotiation. To this end, the participants were invited (while still at the registration stage) to answer questionnaire 01 (available in the appendices section). One of the questions referred to their level of knowledge of each of the 10 systems highlighted for the study.

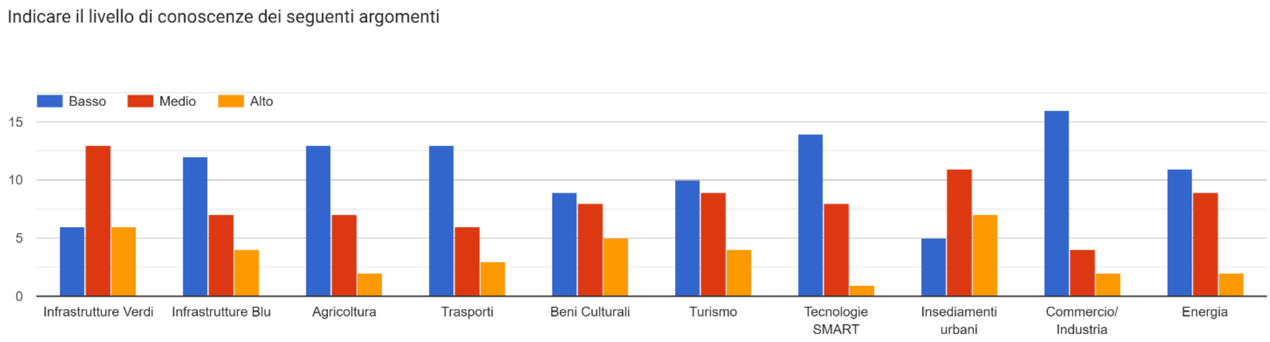


Figure 66: Questionnaire result: Indication of the level of knowledge of each system

According to the choices made by the participants, the type of project to be done by each participant was indicated. Each system had around 2 participants in charge of the projects. This contribution was mandatory and, in addition to this, participants were invited to create other proposals for other systems.

Figure 67: Drawing up design proposals. Source: Author.

Results of the first design proposals:

The first proposals, made individually for each of the systems, are presented below:

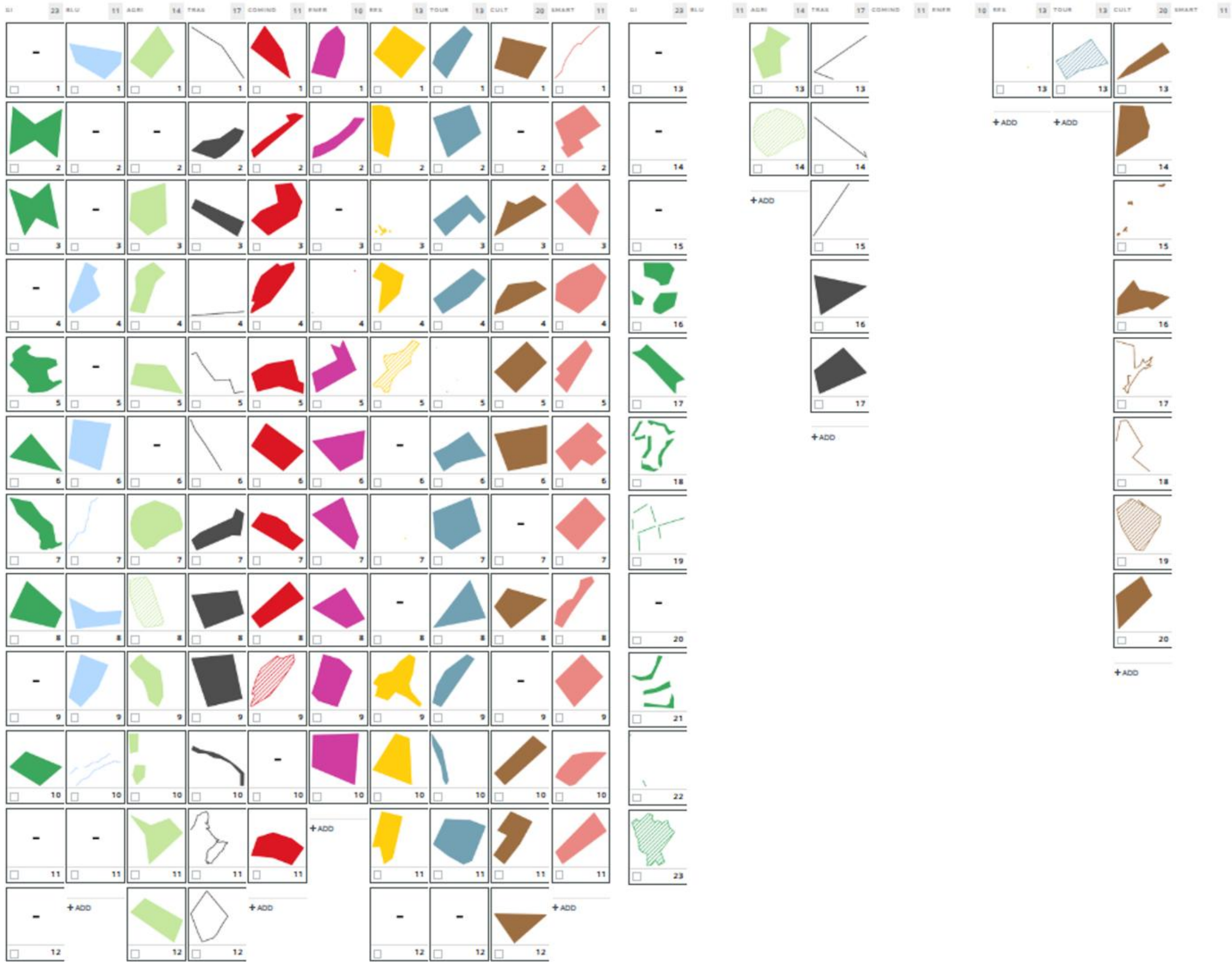


Figure 68: Results of the first design proposals. Source: Author.

The total number of proposals shows a fairly even distribution, with more projects in green infrastructure and the conservation of cultural assets and a smaller number of projects in the blue infrastructure systems (with many redesigns) energy, commerce and industry and smart. The lower number of proposals does not reflect lower priority sectors, but rather the profile of the participants.

	Submitted	Excluded	Remaining
Green Infrastructure	23	9	14
Blue Infrastructure	11	5	6
Agriculture	14	2	12
Transport	17	0	17
Trade and Industry	11	1	10
Energy	10	3	7
Housing	13	4	9
Tourism	13	1	12
Culture	20	3	17
Smart	11	0	11

Tabel 3: Number of projects per system. Source: Author.

Grouped by system, it is possible to see the spatial dimension and distribution of the proposals in the territory. Some systems have had specific interventions, in small areas, such as the energy, commerce/industry and tourism systems. These are proposals in very contained areas, but distributed over the vast area of the Maceratese crater. Others, as well as being more specific, are contained within the urban area, such as the housing and smart systems. Green infrastructure and culture are the systems that have been proposed over a wider area, covering the entire area indicated. This is due to the design of policies for an extensive area, covering the entire eastern part of the area indicated. The cultural sector also had important specific contributions in the historic center, indicating a great concern for the assets destroyed by the earthquake and the reconstruction of a cultural identity in the city. The transport system initially received proposals for the urban area and later extended the area to include the connection with the main neighboring service centers: Foligno, Ascoli Piceno and Ancona.

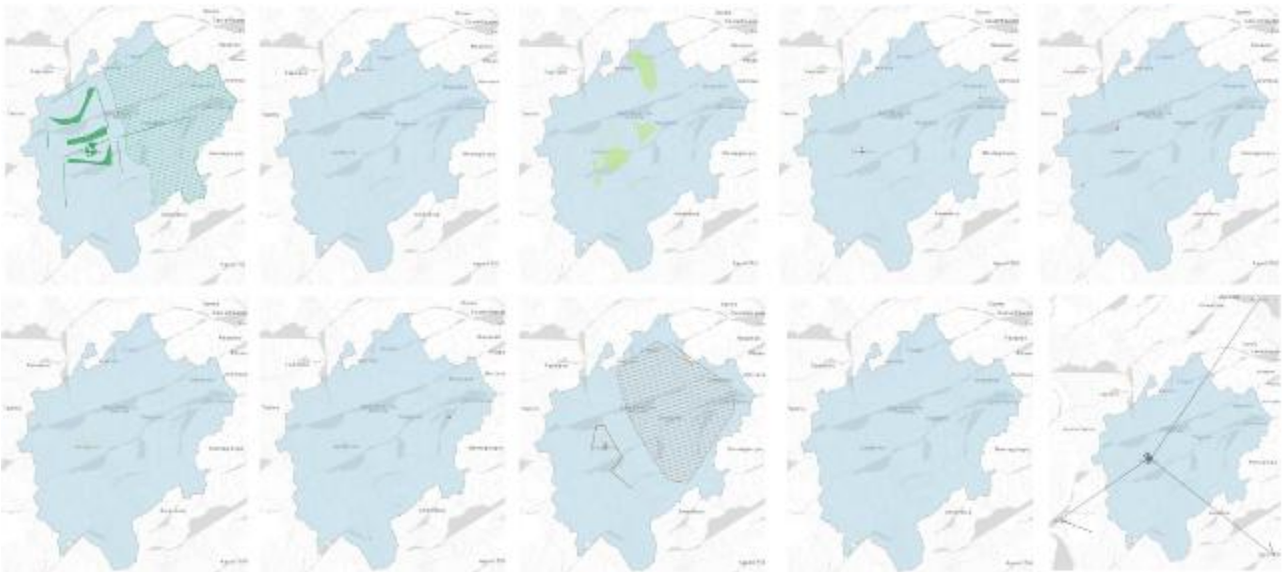


Figure 69: Composite view of all proposals in all systems. Source: Author

According to the final questionnaire (Appendix B), the evaluation model was a useful support for the analysis carried out. On a scale of 1 to 5 where (1 is useless, 2 is not very useful, 3 is useful, 4 is very useful and 5 is very useful), 57.1% of the answers were very useful, 28.6% were very useful and 14.3 were useful. This result is shown in the comparison between the final analyses and the corresponding evaluation map:

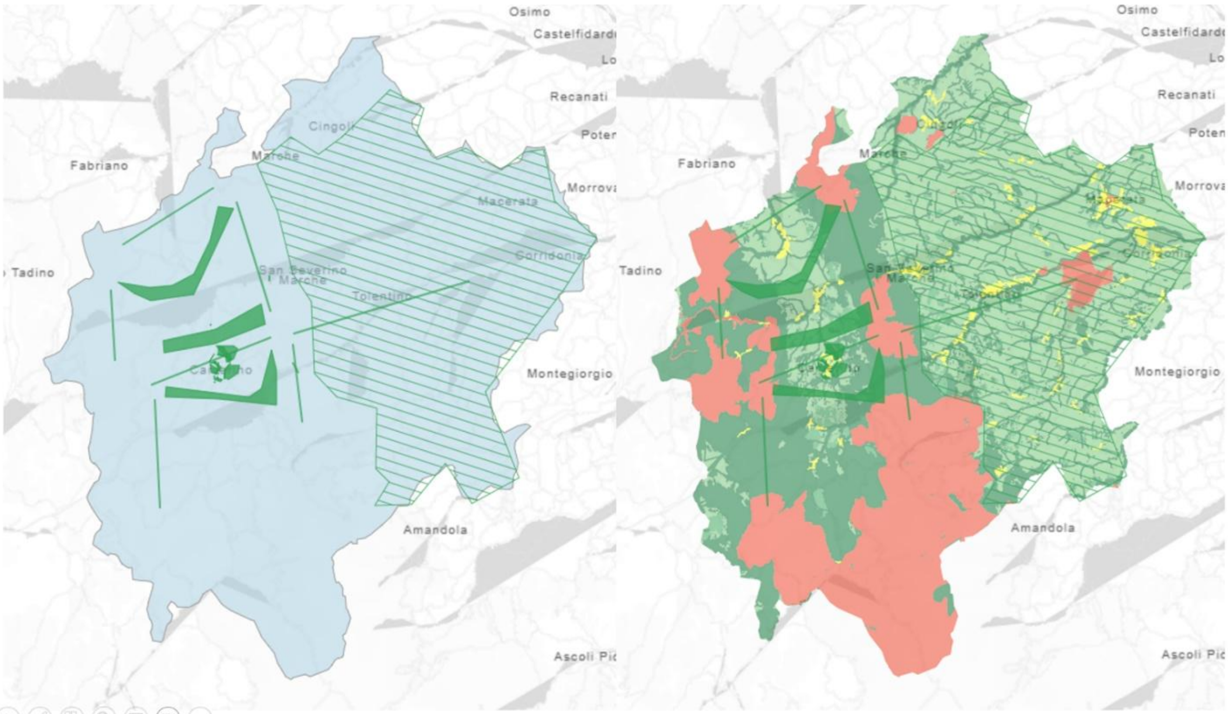


Figure 70: The relationship between the Green Infrastructure System and the Evaluation Map. Source: Author

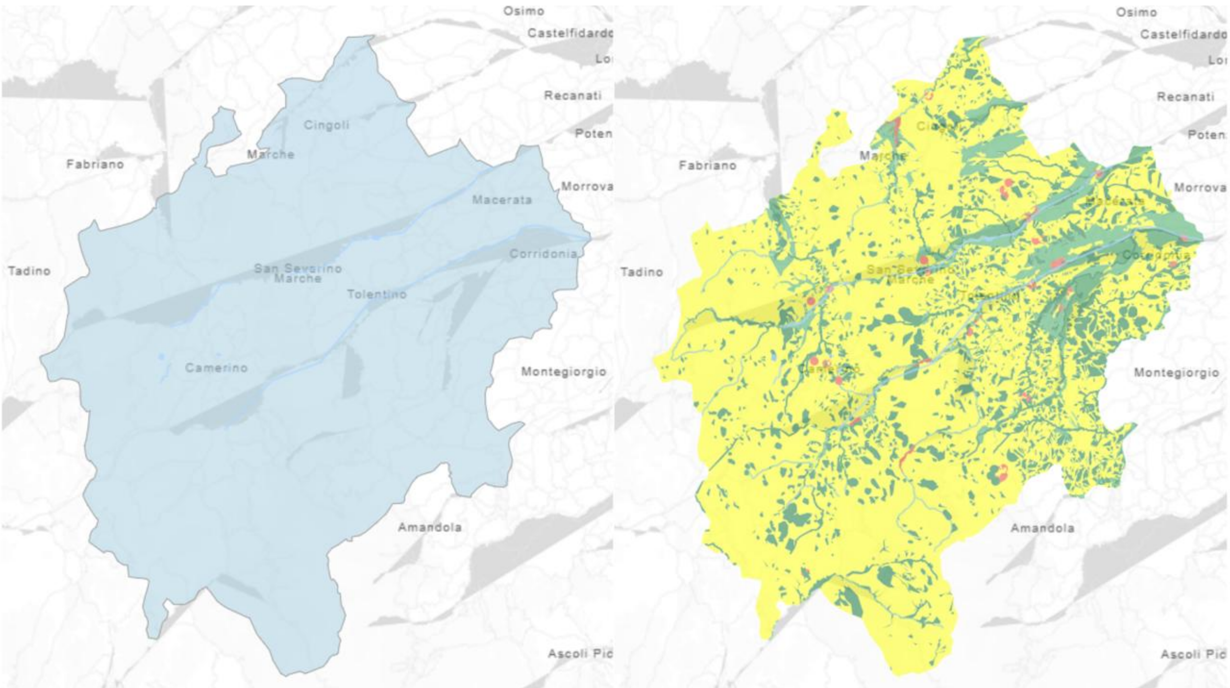


Figure 71: The relationship between the Blue Infrastructure System and the Evaluation Map. Source: Author

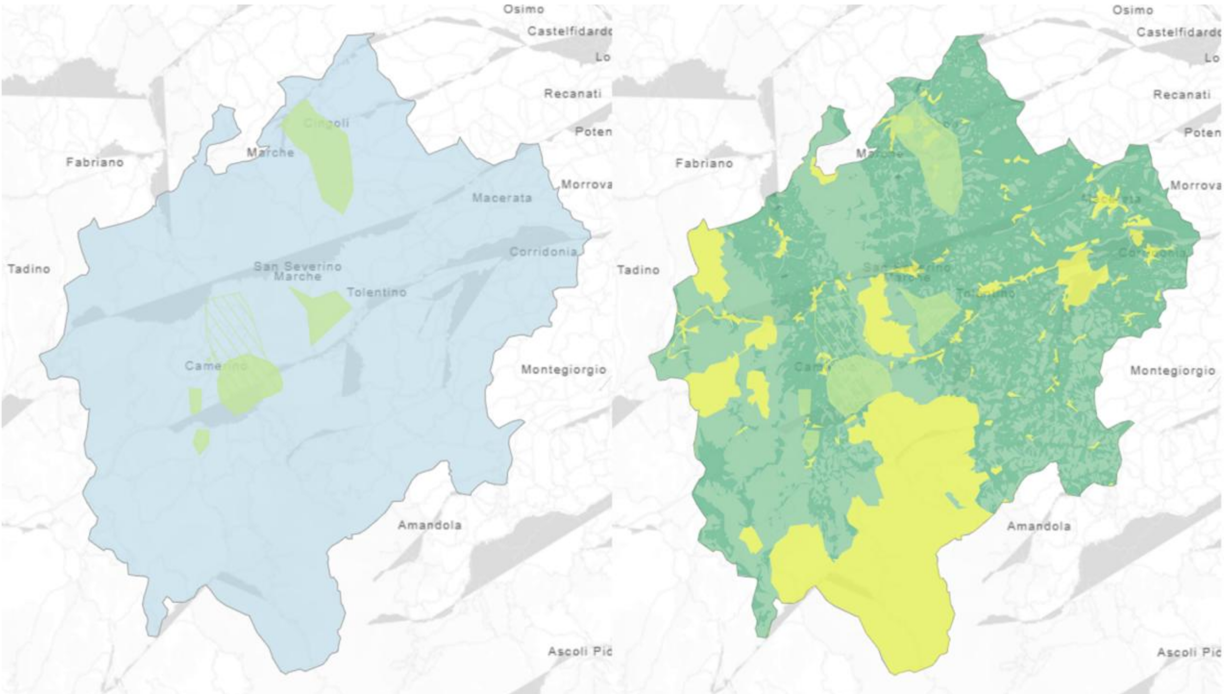


Figure 72: The relationship between the Agriculture System and the Evaluation Map. Source: Author

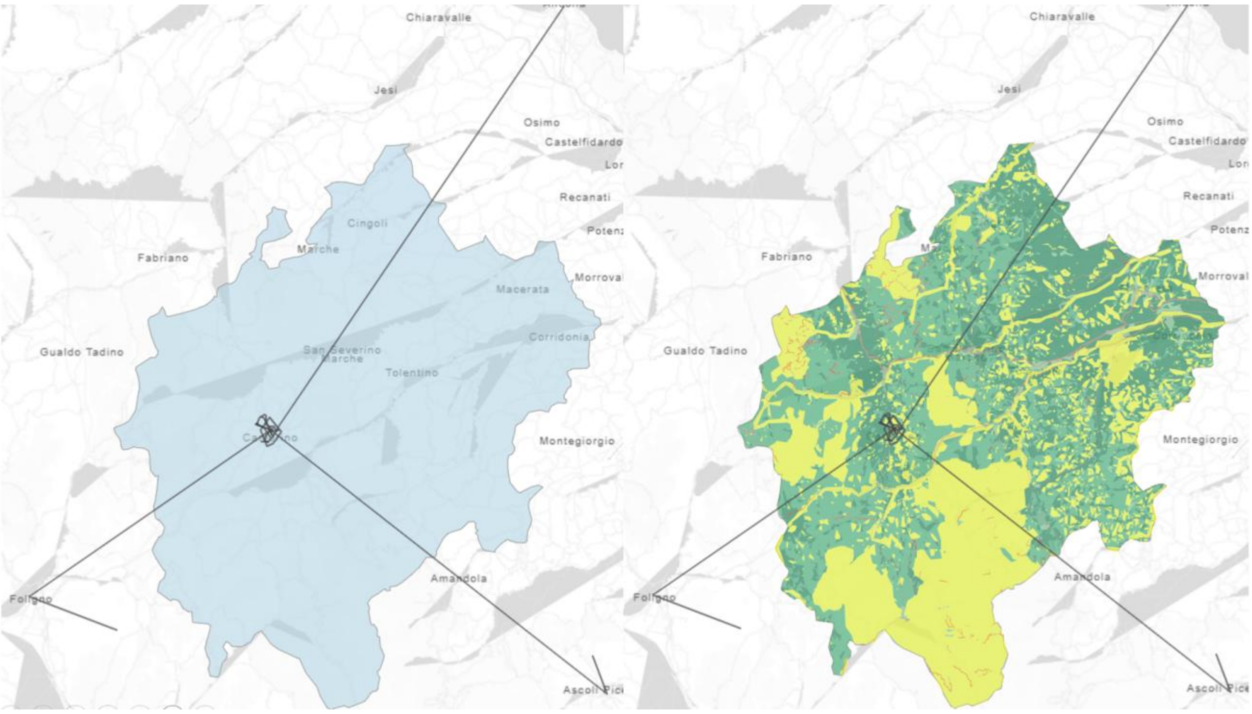


Figure 73: The relationship between the Transportation System and the Evaluation Map. Source: Author

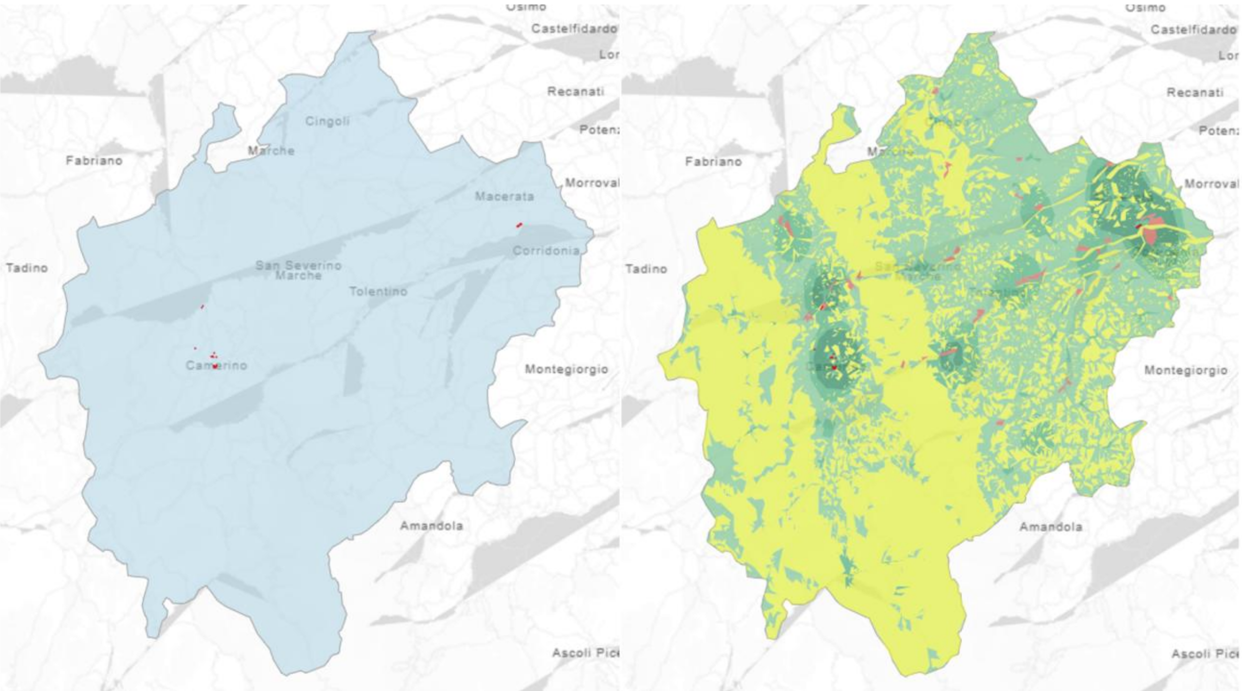


Figure 74: The relationship between the Trade and Industry System and the Evaluation Map. Source: Author

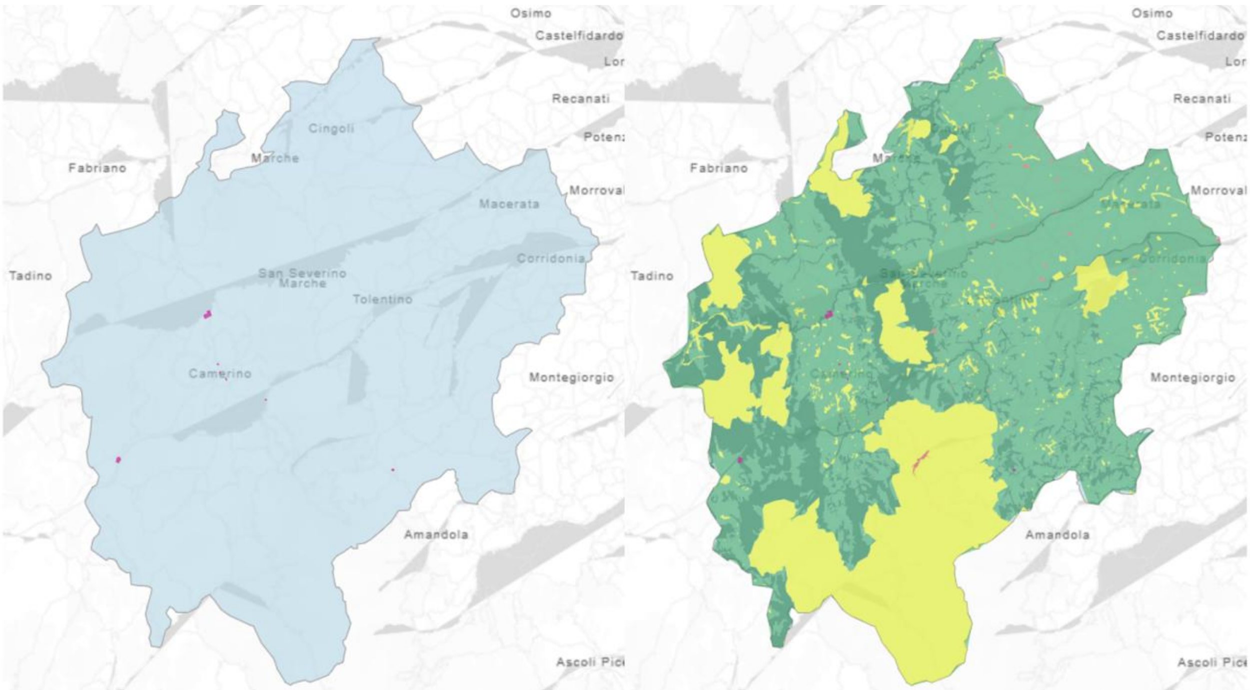


Figure 75: The relationship between the Energy System and the Evaluation Map. Source: Author

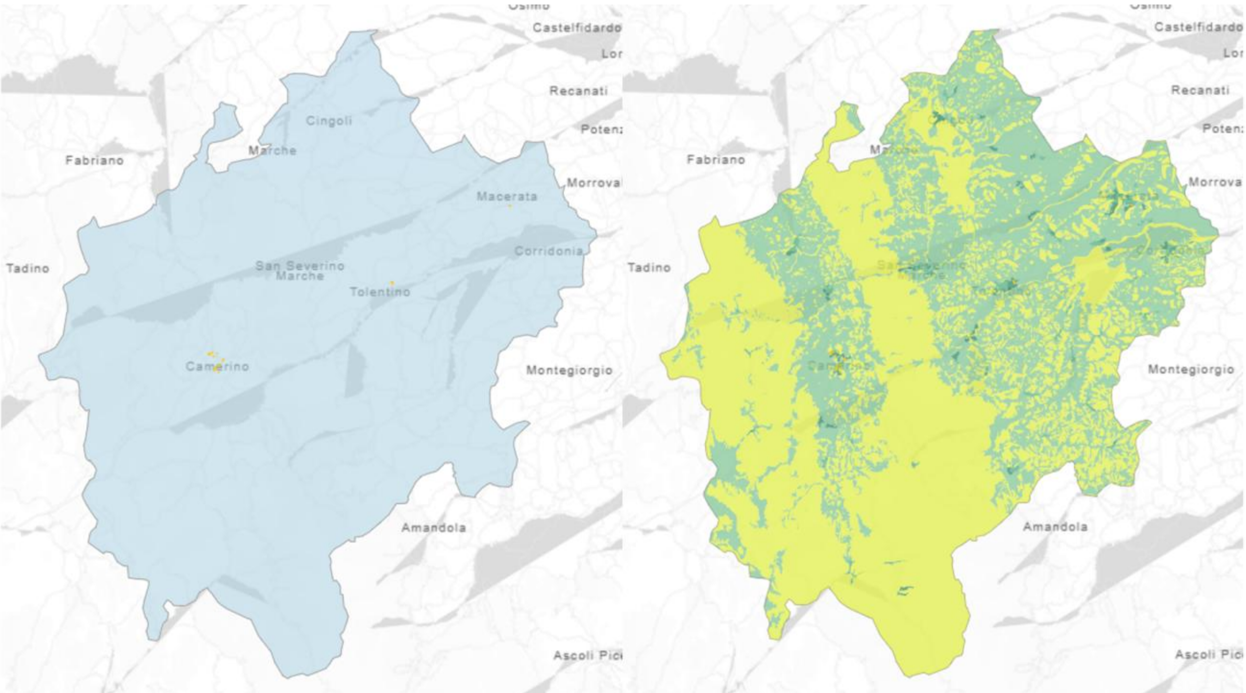


Figure 76: The relationship between the Housing System and the Evaluation Map. Source: Author

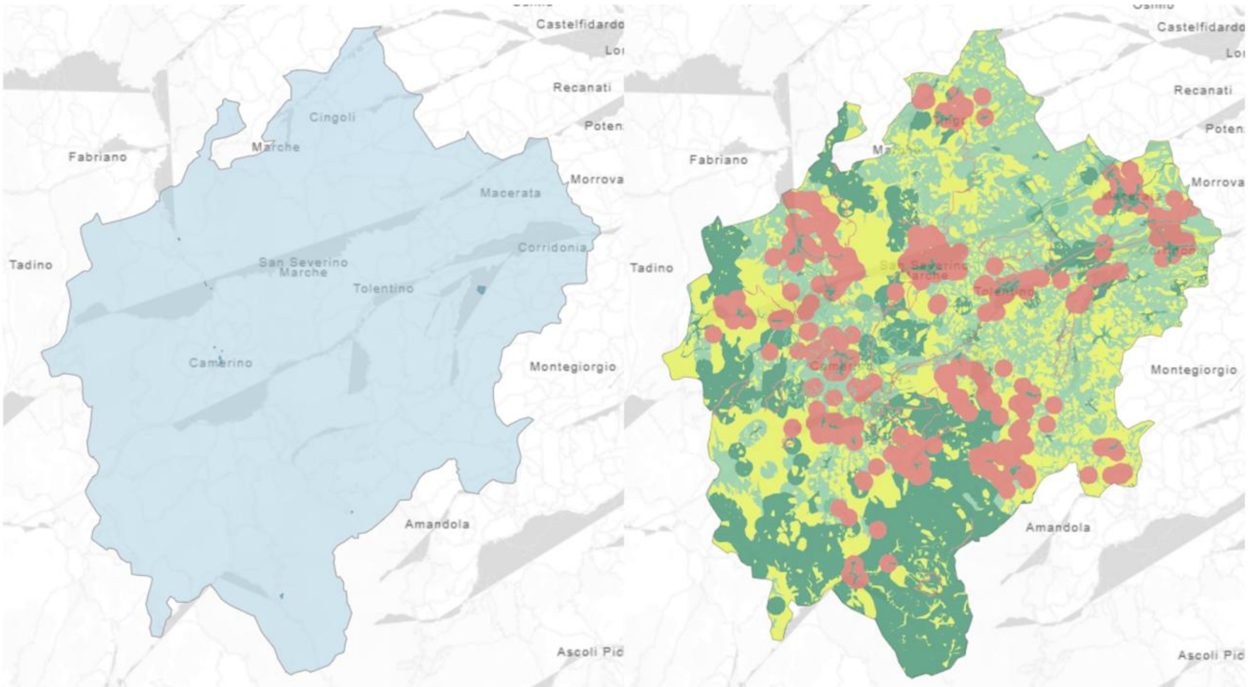


Figure 77: The relationship between the Tourism System and the Evaluation Map. Source: Author

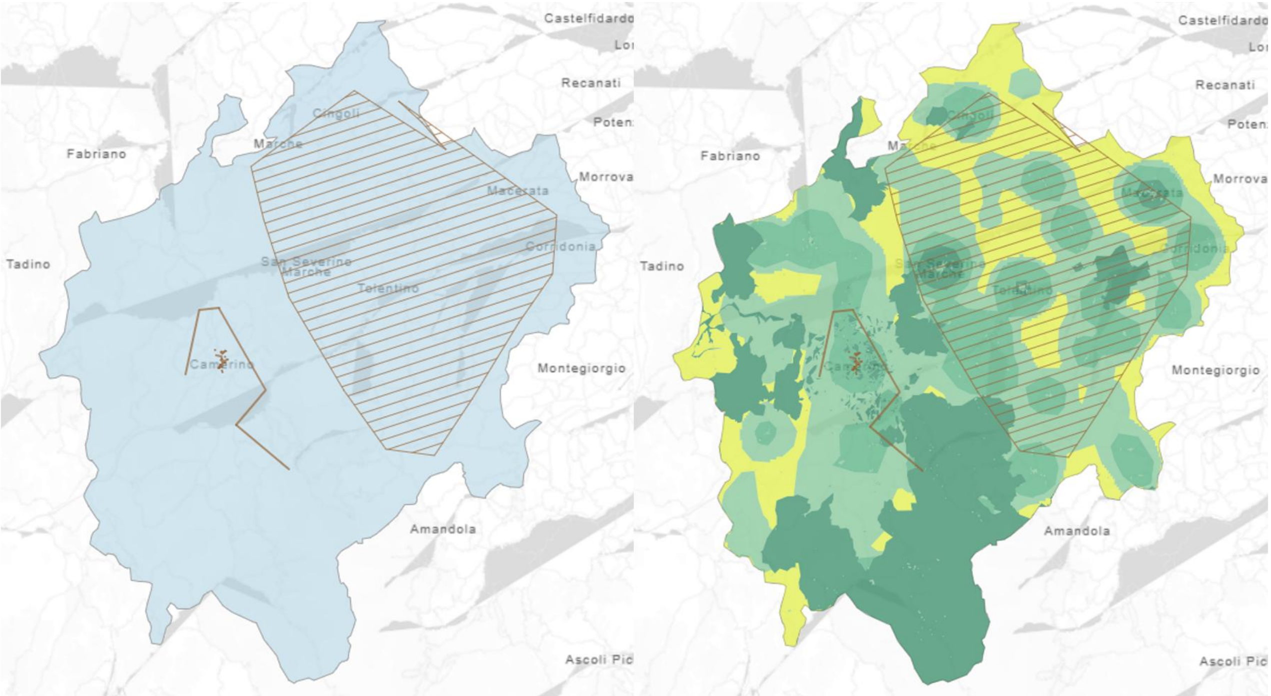


Figure 78: The relationship between the Culture System and the Evaluation Map. Source: Author

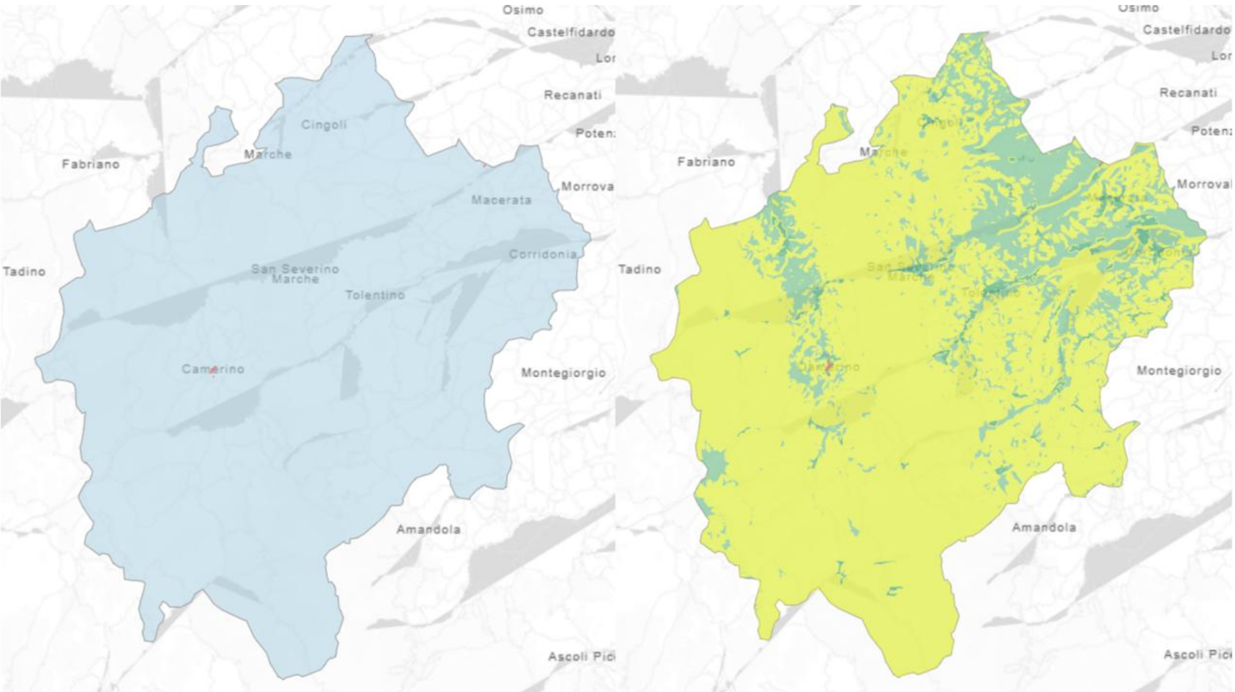


Figure 79: The relationship between the SMAR System and the Evaluation Map. Source: Author

All the proposals are presented separately in Appendix C. In general terms, the proposals presented in the first phase are summarized as follows:

The Green Infrastructure system at the provincial scale has primarily generated projects aimed at enhancing connections between protected natural areas through the establishment of ecological corridors. One proposal promotes the implementation of Ecological Openings for Permeability, while the only policy-based measure proposes reforestation interventions in degraded areas across a vast portion of the eastern side of the mapped territory.

At the urban level, most projects focus on the creation of green corridors or green belts along the urban periphery, bordering areas affected by urban sprawl. Additional proposals involve smaller-scale interventions in the historic center, such as the development of a park in Piazza Giuseppe Mazzini, and in earthquake-affected areas, such as the site of the demolished courthouse or the prosthetic farm proposed in the area of the former Ugo Betti school. Reforestation areas were also proposed on the outskirts of the city.

The Blue Infrastructure system at the provincial level includes proposals for irrigation water reservoirs (2 proposals) and river parks (2 proposals). Other interventions concern the implementation of a constructed wetland system (impianto di fitodepurazione) and the establishment of a new thermal area. No specific proposals were submitted at the urban scale.

For the Agricultural system at the provincial level, the proposals focus on strengthening local producers, with strategies for pig farming, hydrogeological risk mitigation in agricultural areas, and a policy supporting the creation and maintenance of agritourism. At the urban level, the initiatives include zero-kilometer markets, community gardens, local production, and educational laboratories.

In the Transport system, the initial proposals concentrated on the urban area, aiming to promote soft and sustainable mobility. Ideas included infrastructural “funnels” to overcome accessibility barriers, bike-pedestrian paths linking student and sports zones, car sharing, electric scooter rental, and charging stations for bicycles and scooters. The project area was later expanded to connect the city to nearby service centers through direct bus routes to Foligno, Ascoli Piceno, and Ancona.

Within the Trade and Industry system, the proposals aim to enhance the local product economy, with ideas such as distribution hubs, diffuse markets, business centers, and a rural spa. Other projects are directed toward technological innovation and start-up support, including the establishment of science parks and incubation spaces in existing buildings, as well as the completion of the industrial zone.

In the Energy system, the projects focus on increasing the production and use of renewable energy sources. Proposals include schools and parking lots powered by clean energy, along with incentives for installing photovoltaic panels on rooftops in the industrial zone. For clean energy generation, proposals include hydroelectric plants, geothermal facilities, and the use of biomass.

The Housing system emphasizes the city's student-oriented identity and supports housing solutions for vulnerable populations. Proposals aim to construct new facilities or repurpose disused buildings - such as the former hospital and emergency residences - to expand housing options for students, foreign nationals, the elderly, and persons with physical disabilities. Broader initiatives suggest urban densification in the northeastern area of Tolentino, adjacent to strategic infrastructures.

Tourism proposals include the development of public space networks, promotion of scientific tourism, and the enhancement of the botanical garden with rare plant species. One project also suggests repurposing emergency housing for tourism purposes.

In the Cultural system, a wide range of activities is proposed: a multifunctional theater-cinema, a geological and seismic museum, open-air cinema, bike workshop, and an art restoration center. Additional initiatives include the creation of smart incubators in emergency buildings, gardens and dialogue spaces for students, and themed tourist itineraries, such as religious-cultural routes, castle tours, and hill lake circuits.

The SMART system presents diverse proposals, many of which intersect with other systems. These include a digital trail and museum, tactical urbanism projects, and the reactivation of the Municipal Theater and cinema in Piazza Garibaldi in the historic center. Additional proposals involve bike paths, technology hubs, the smart transformation of a central pharmacy, networks of public squares for physical activity, and information nodes. One project proposes a smart working hub on the site of the demolished courthouse.

4.4.5 Impact Model

Once the projects have been drawn up individually, according to each person's skills, we move on to the process of evaluating the proposals and negotiating. This stage of the process is usually carried out with a group of people belonging to the same sector: Committee, Public Administration, Traders, Industrialists, etc. In our case, due to the lack of some of these characters, we decided to draw lots in which each participant would play a role representing the following groups:

1. Public administration: administrators and various technical sectors;
2. Rural: farmers and rural entrepreneurs;
3. Developers: people linked to trade and industry;
4. Green: people linked to the conservation of natural resources;
5. Civil protection: people linked to disaster risk reduction;
6. Culture: people linked to the cultural sector in general, from conserving cultural assets to encouraging tourism.

The project evaluation and selection process was conducted by thematic groups, each responsible for analyzing and defining which proposals best represented their interests and functions within the collective. Decisions were made collaboratively, allowing participants to select or reject projects based on their relevance to the local context. The evolution of the groups' choices was documented in graphical representations that highlight both the overall vision of the proposals and specific details of the urban fabric.

The public administration group prioritized social housing, especially for the most vulnerable population. Some buildings in the historic center were designated for this purpose, while a portion of the SAE (San Paolo) was proposed for social housing. Additionally, an integrated mobility plan was developed, including a cycle-pedestrian system connecting to the new Pedemontana infrastructure and an interconnected transport system, such as the cable car designed by another group. Other planned interventions include a mechanized parking facility and the installation of solar panels on the roofs of schools and industrial buildings. Soil preservation against hydrogeological instability was considered through the introduction of sustainable agricultural practices. The requalification of emblematic buildings, such as the *cinema comunale*, was also suggested, along with the enhancement of urban green spaces for recreational activities.

The Culture group emphasized the creation of cultural and religious routes, leveraging the region's historical and natural resources. A tourism circuit was proposed to connect local castles via existing trails. Considering disaster resilience, a geological-seismic museum was conceived to document earthquake phases and inform on response strategies at each stage of the disaster. Additionally, an enogastronomic route was planned to promote tourism and encourage the production of zero-kilometer food products. A restoration laboratory was envisioned for the rehabilitation of underutilized buildings. To reduce traffic in the historic center, the implementation of mechanized routes, such as the cable car, was suggested to connect the central area with Pedemontana.

The developers' group focused on integrating Camerino with other strategic points in the territory, improving connectivity with services and mobility infrastructure. The plan included the creation of a green belt around the city, linking natural and urban areas through cycling and pedestrian paths. Interventions also covered the reuse of SAE housing units once they were no longer needed. Given the local topography, charging stations for electric bicycles were planned along the cycling routes.

The environmental group proposed a territorial resilience project based on connecting existing green areas through ecological corridors and ecological corridors for biopermeability. The requalification of fluvial areas included the creation of parks and hillside lakes, promoting water conservation and biodiversity. Although cultural and tourism projects were considered, priority was given to residential initiatives aligned with environmental requalification policies.

The civil protection group assessed the projects from the perspective of natural risk reduction, ensuring that no proposal increased population exposure to disasters. The blue infrastructure was reinforced with the creation of agricultural reservoirs in higher areas to mitigate water scarcity and support emergencies such as fires. Some proposals were discarded due to potential obstacles to territorial development or population safety. Prioritized interventions aimed at reducing vulnerabilities, such as the creation of housing for the elderly instead of new recreational areas. Furthermore, the group encouraged the introduction of green areas in the urban environment, increasing soil permeability, lowering local temperatures, creating shaded zones, and establishing botanical gardens. The resilience strategy was expanded to the entire region, considering the interdependence between urban and rural ecosystems.

The rural group focused on strengthening the agroecological and forestry system around Camerino, promoting the integration of Monte Faito Park and Monte Sibillini Park. The expansion of wooded areas was encouraged for environmental and energy benefits, including the use of wood in biomass systems and the exploitation of thermal water for hydrothermal energy production. Economic revitalization of Camerino's center was also pursued through the creation of a diffuse commercial center for the sale of high-quality local products, alongside the reinforcement of the region's traditional pig farming. The group's guiding principle was the preservation of existing resources, avoiding unnecessary urban expansion and prioritizing the requalification of available urban spaces and services.

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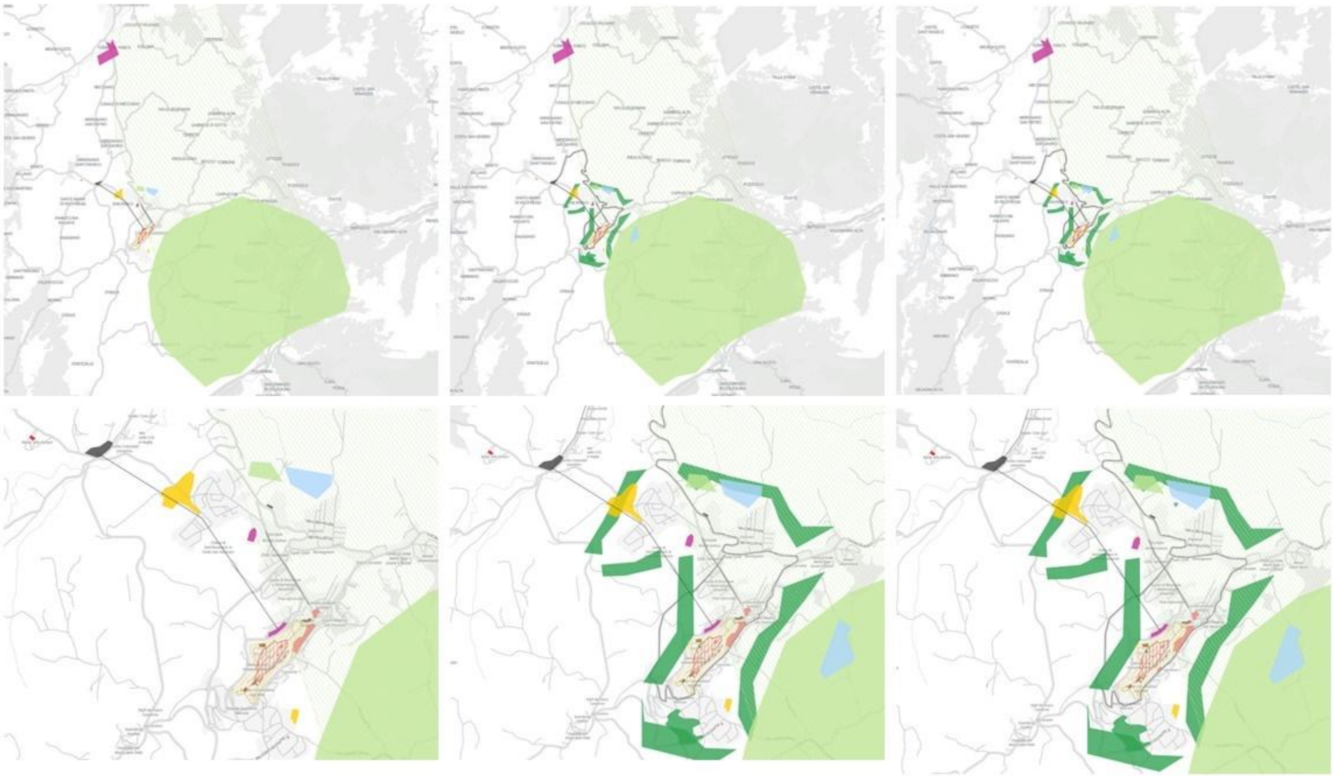

Figure 80: Evolution of the Commune's decision. Source: author.

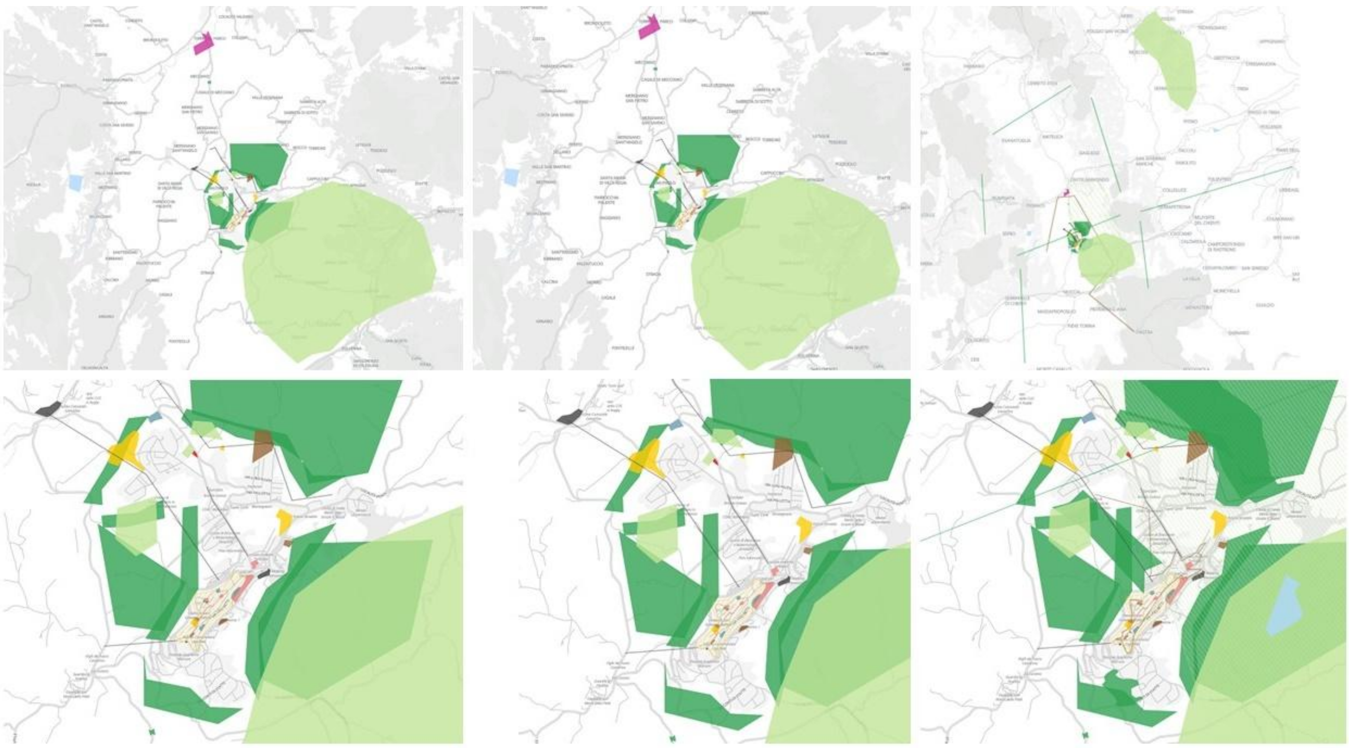

Figure 81: Evolution of the Culture Group's decision. Source: author.

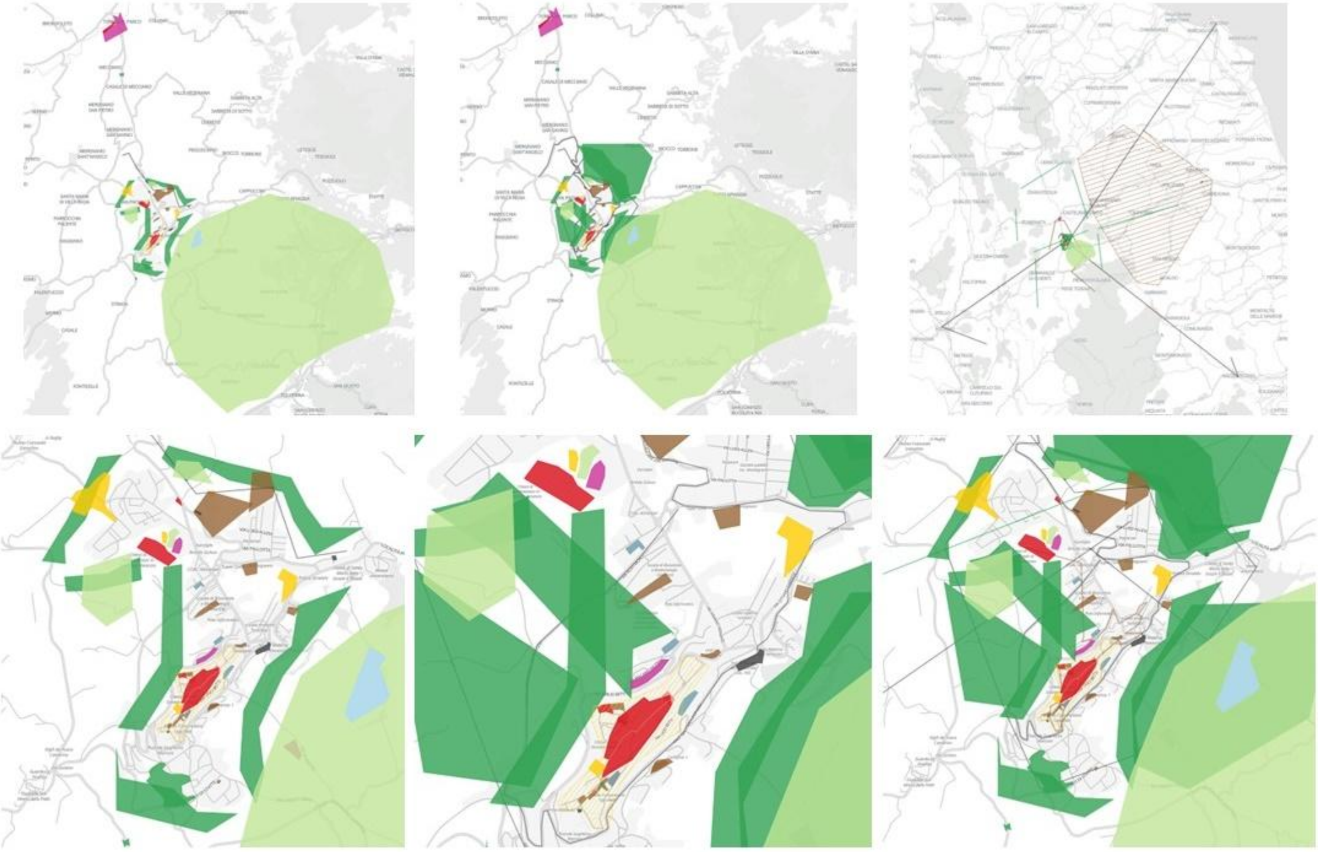

Figure 82: Evolution of the Developers Group decision. Source: author.

Figure 83: Evolution of the Green Group's decision. Source: author.

Figure 84: Evolution of the Civil Protection Group's decision. Source: author.

Figure 85: Evolution of the Rural Group's decision. Source: author.

Negotiation between coalitions

Once the appropriate proposals to represent the interests of each group had been evaluated, reformulated and decided on together, the first coalitions were formed to evaluate and negotiate the proposals between the different groups. To do this, a presentation was made of the proposals chosen by each group and participants were invited to vote to assess the affinities between them. The result was the following table:

	Green	Developers	Rural	Pub. Adm	Civ. Prot.	Cult	
Green		+	++	-	+	-	+2
Developers	+		-	--	-	+	-2
Rural	++	-		++	--	++	+3
Pub. Adm	--	+	--		++	+	0
Civ. Prot.	++	++	+	++		+	+8
Cult	-	++	++	+	+		+5

In this way, the groups that had more affinity were regrouped and the group with the most votes was given priority within the coalition. The groups defined were:

- Public Administration and Civil Protection (Civil Protection has priority vote)
- Green and Developers (Green has priority vote)
- Culture and Rural (Culture has priority vote)

Each pair of sectors was responsible for choosing the proposals together, generating a unified result. The GeoDesignHub platform allows you to view a matrix of the previously chosen proposals and the final result of each coalition, as shown below:

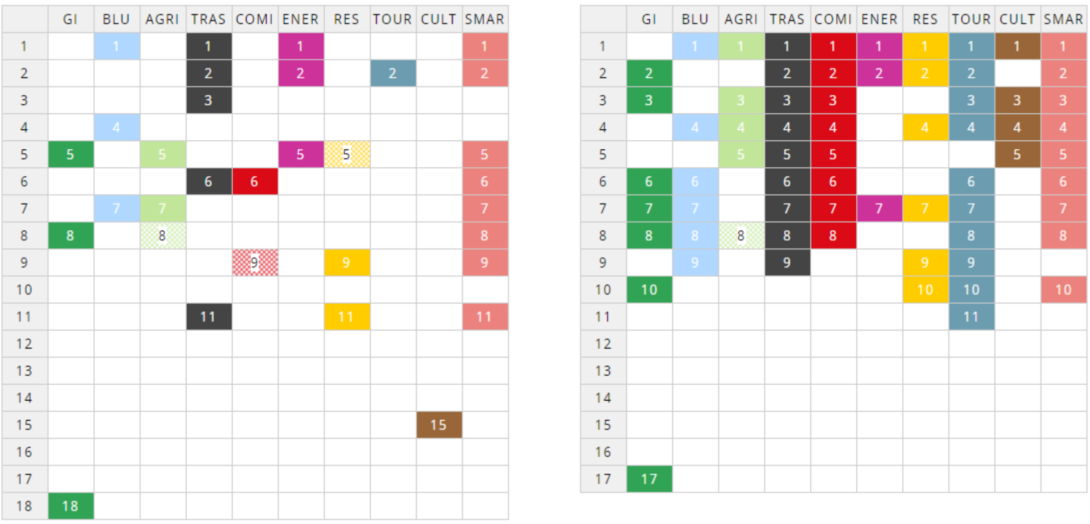

Figure 86: Comparison between the Administration and Civil Protection Proposals

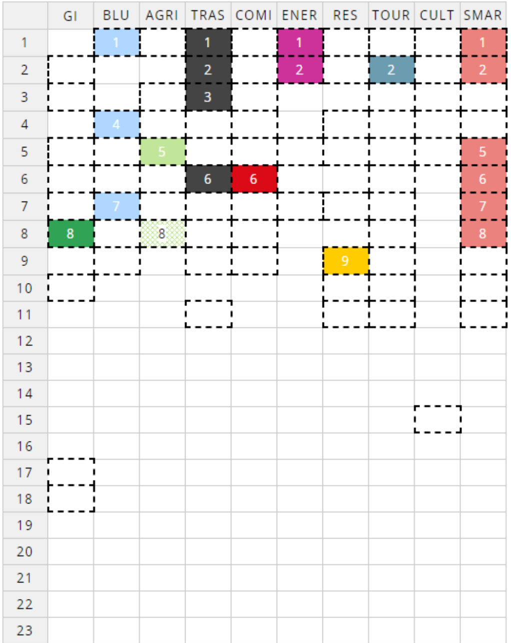

Figure 87: Negotiation between Administration and Civil Protection

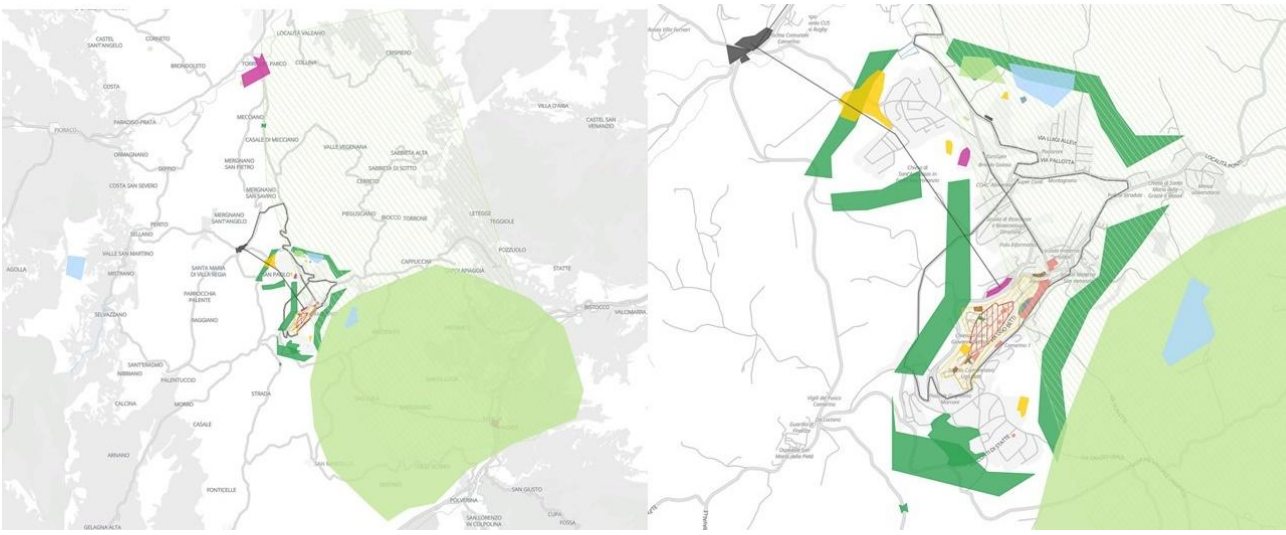

Figure 88: Result of the negotiation between the Public Administration and Civil Protection. Source: Author.

	GI	BLU	AGRI	TRAS	COMI	ENER	RES	TOUR	CULT	SMAR
1			1	1	1	1		1	1	1
2				2		2				
3								3		
4		4						4		
5	5	5				5	5			
6	6							6		6
7	7	7	7	7			7			
8	8	8	8		8				8	8
9			9					9		
10	10	10								
11										
12				12				12		
13										
14									14	
15										
16	16									
17	17									
18	18									
19	19								19	
20										
21	21									
22	22									
23	23									

	GI	BLU	AGRI	TRAS	COMI	ENER	RES	TOUR	CULT	SMAR
1					1	1	1	1	1	1
2	2				2	2	2			
3	3		3	3		3		3	3	3
4		4	4		4		4	4	4	4
5	5		5	5	5	5	5		5	5
6	6								6	
7	7	7	7	7	7	7				
8	8	8		8	8				8	
9				9			9	9		
10	10						10		10	
11				11						
12				12						
13				13					13	
14				14					14	
15				15					15	
16	16									
17	17								17	
18	18								18	
19	19								19	

Figure 89: Comparison between Green's and Developers' proposals. Source: Author.

	GI	BLU	AGRI	TRAS	COMI	ENER	RES	TOUR	CULT	SMAR
1					1	1		1	1	1
2						2				
3								3		
4		4						4		
5	5					5	5			
6	6									
7	7	7	7	7						
8	8	8			8				8	
9								9		
10	10									
11										
12				12						
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14									14	
15										
16	16									
17	17									
18	18									
19	19								19	
20										
21										
22										
23										

Figure 90: Result of the negotiation between Green and Dev. Source: Author.

Figure 91: Result of the negotiation between Green and Developers. Source: Author.

	GI	BLU	AGRI	TRAS	COMI	ENER	RES	TOUR	CULT	SMAR
1			1	1	1		1	1	1	1
2	2			2						2
3	3		3						3	
4		4		4			4		4	4
5	5	5	5	5		5	5			
6	6	6		6				6		6
7	7	7	7	7				7		
8	8	8	8	8						8
9		9	9				9	9		
10	10						10		10	
11									11	
12									12	
13										
14									14	
15										
16	16									
17	17								17	
18	18								18	
19	19									

	GI	BLU	AGRI	TRAS	COMI	ENER	RES	TOUR	CULT	SMAR
1			1		1	1	1	1		1
2	2				2	2	2	2		2
3	3		3							3
4		4	4		4			4		4
5	5		5			5	5		5	5
6		6			6			6		6
7		7	7			7		7		7
8	8		8			8		8		8
9					9	9	9	9		9
10			10		10		10			
11			11				11		11	
12									12	
13									13	
14									14	
15									15	
16	16								16	
17	17									
18	18									
19										
20										
21	21									

Figure 92: Comparison between Culture and Rural proposals. Source: Author.

	GI	BLU	AGRI	TRAS	COMI	ENER	RES	TOUR	CULT	SMAR
1			1		1		1	1		1
2	2									2
3	3		3							
4		4								4
5	5		5			5	5			
6		6						6		6
7		7	7					7		
8	8		8							8
9							9	9		
10							10			
11									11	
12									12	
13										
14									14	
15										
16	16									
17	17									
18	18									
19										
20										
21										
22										
23										

Figure 93: Result of the negotiation between Culture and Rural. Source: Author.

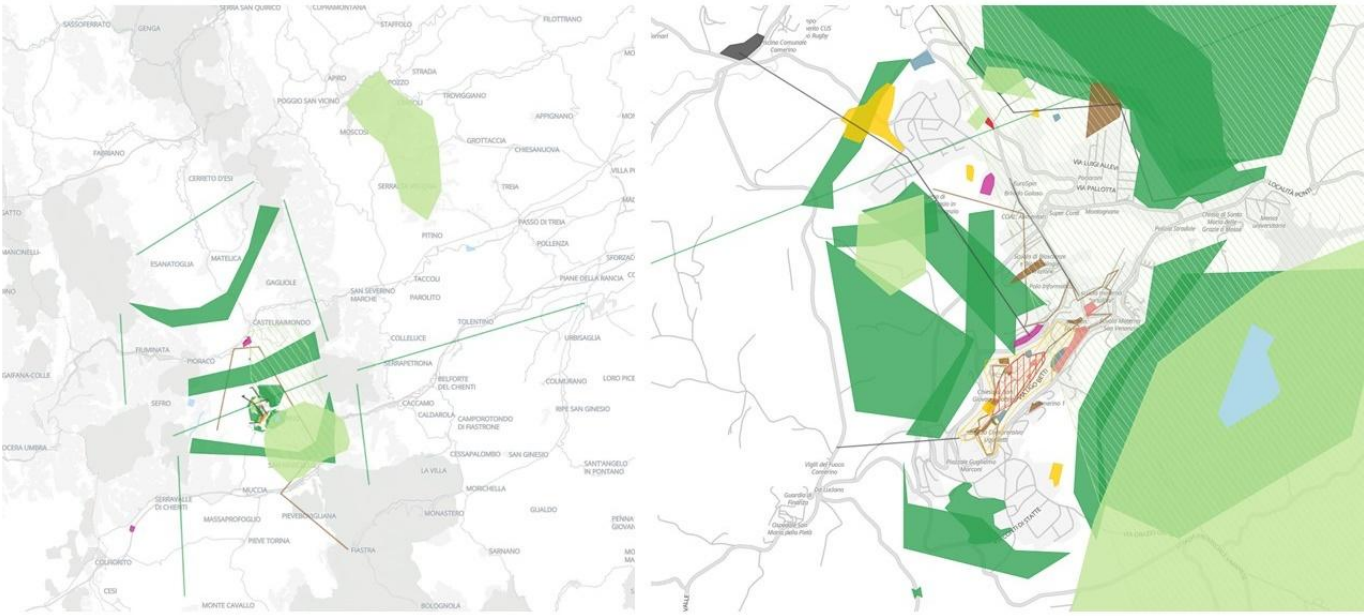

Figure 94: Result of the negotiation between Culture and Rural. Source: Author.

4.4.5 Decision Model

For the final decision, the coalitions were voted on again:

	Pub. Adm/Civ. Prot.	Green/Develop	Culture/Rural
Pub. Adm/Civ. Prot.		-	-
Green/Develop	-		+
Culture/Rural	+	+	

In this way, Green/Dev and Culture/Rural had the power of decision, while Pub. Adm/Civil Protection had the power of speech. In the event of disagreements between the groups in the discussion, the decision would be made by the Pub. Adm/Prot.Civ group.

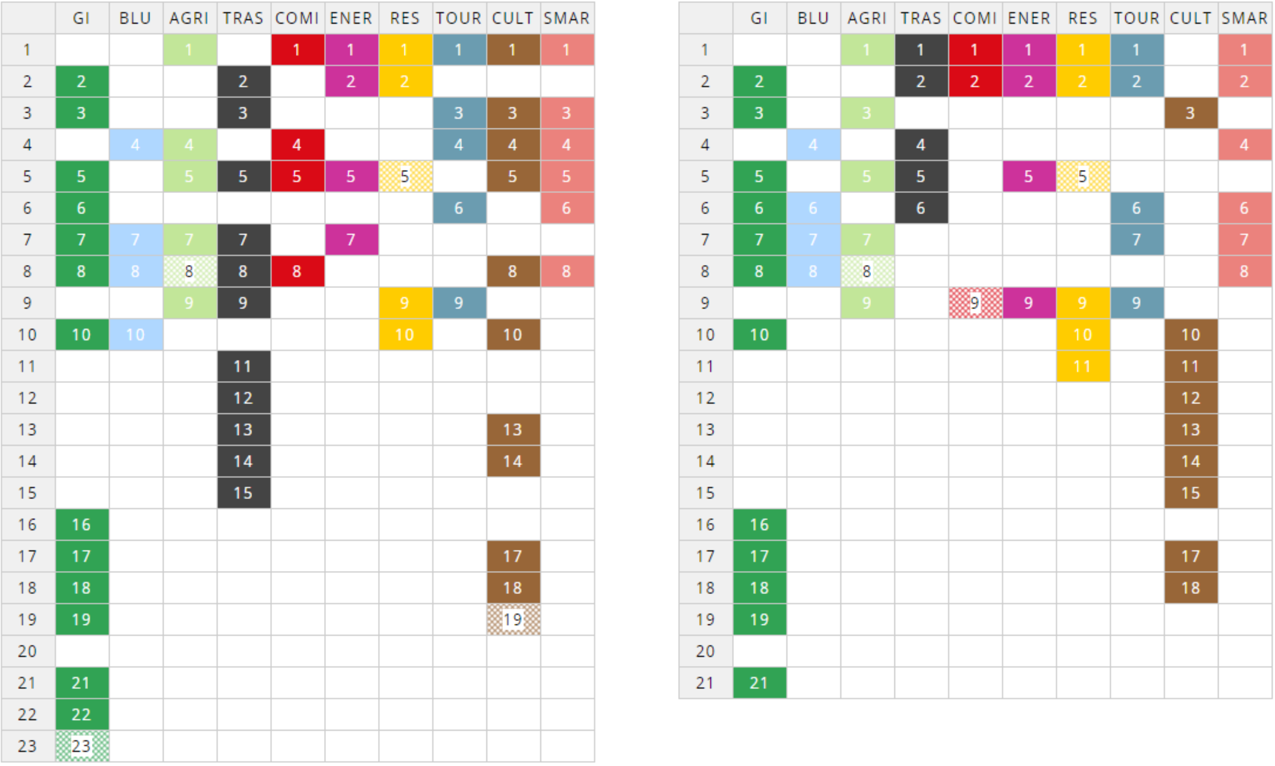

Figure 95: Comparison grid. Source: Author.

	GI	BLU	AGRI	TRAS	COMI	ENER	RES	TOUR	CULT	SMAR
1			1	1	1	1	1	1		1
2	2			2		2	2	2		
3	3			3				3	3	
4		4								4
5	5		5	5		5	5		5	5
6	6	6		6				6		6
7	7	7	7	7						7
8	8	8	8							8
9			9		9		9	9		
10	10	10					10		10	
11				11			11		11	
12				12						
13				13					13	
14				14					14	
15				15					15	
16	16									
17	17								17	
18	18								18	
19	19								19	
20										
21	21									
22	22									
23	23									

Figure 96: Final negotiation: proposals accepted in the design synthesis. Source: Author.

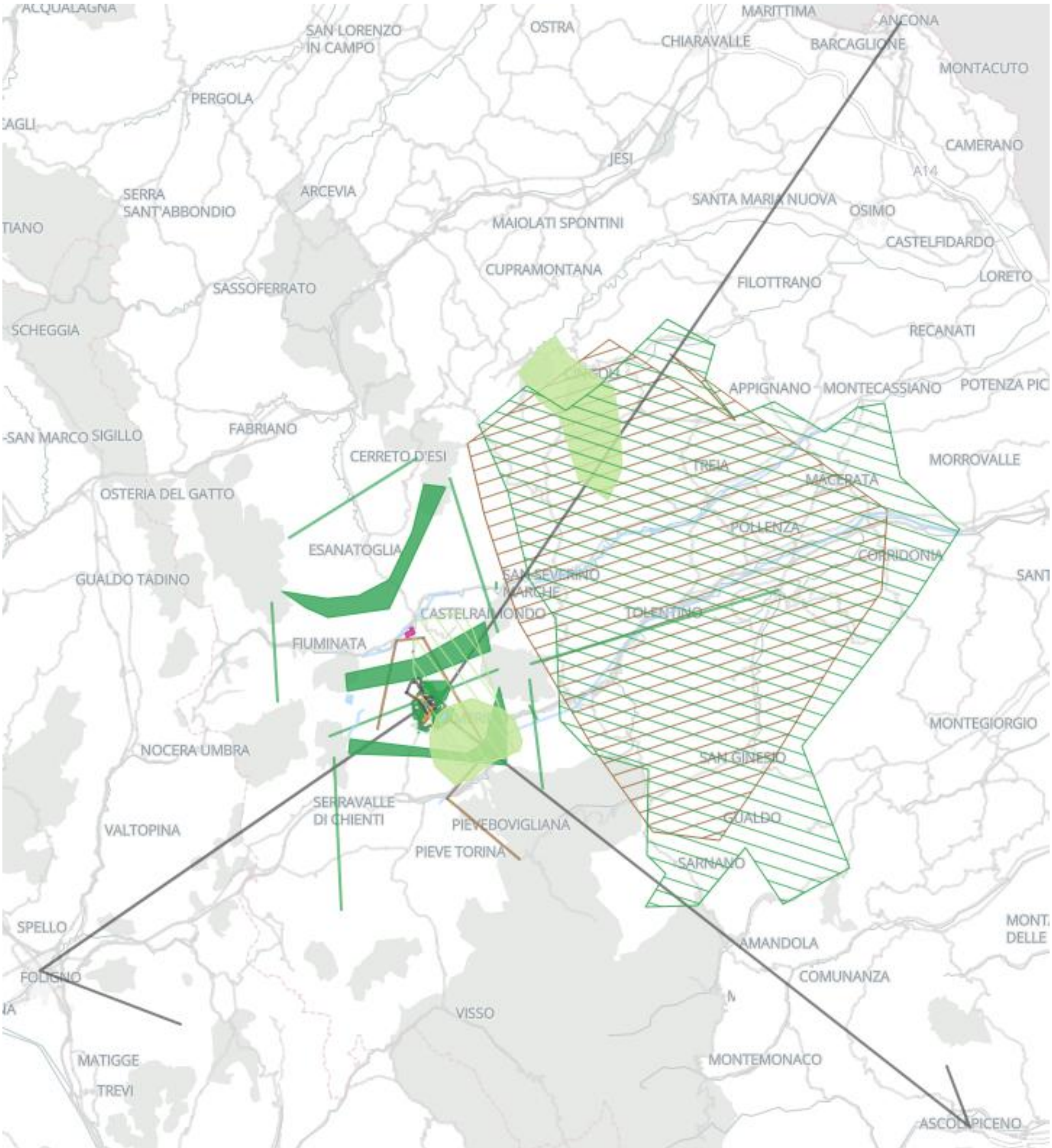

Figure 97: Final summary - comprehensive area. Source: Author.

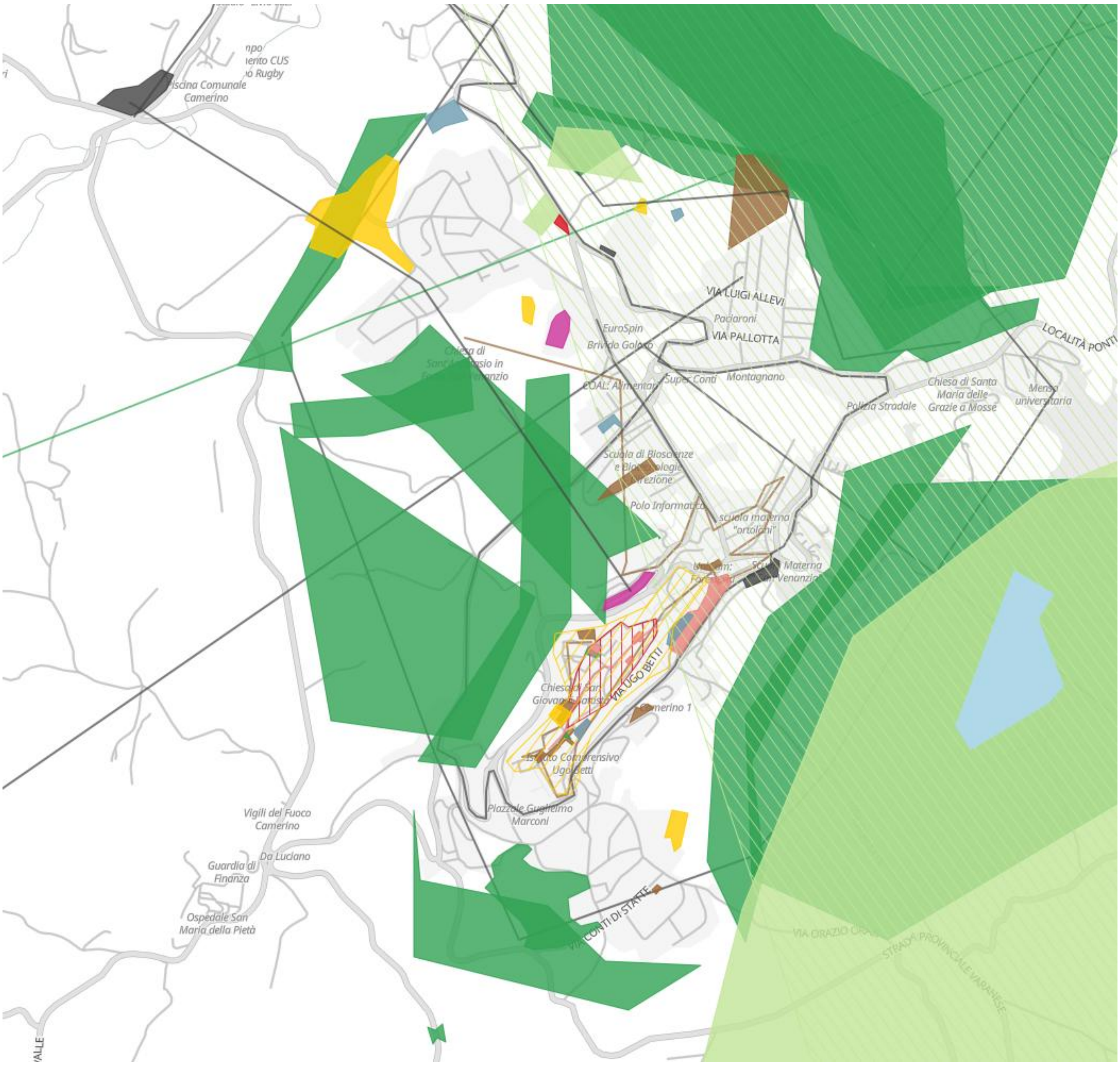

Figure 98: Final overview: city context. Source: Author

The final proposal consists of:

In the historic center:

1. Integrated residences for vulnerable populations (elderly, foreigners, people with motor disabilities)
2. Assisted healthcare residence in the old hospital
3. Geological-seismic museum
4. Network of places for physical activities such as yoga and meditation
5. Improvement and development of the botanical garden
6. New contemporary architectures in the old town
7. Religious-cultural route
8. Restoration and requalification of the *Palazzo delle Esposte*
9. Tactical urbanism interventions
10. Diffuse commercial center
11. An urban park in the demolition area of the courthouse

In the city's outskirts:

1. Parking areas with charging stations
2. Solar energy in schools
3. Subsidized rentals in the *SAE San Paolo* areas
4. Spaces for dialogue and exchange
5. Green Belt
6. Urban reforestation areas
7. Network of public places for the local community
8. Agriculture designed to mitigate hydrogeological instability
9. Network of bike and hike hubs
10. Cycle-pedestrian path to connect green areas
11. Adolescents' house
12. SAE 2.0 – social housing
13. Network of places to share local products

In the wider area:

1. Incentives for photovoltaic installations on industrial sector rooftops
2. Ecological corridor
3. New thermal area
4. New interchange parking lot at the junction with the Pedemontana road
5. River parks
6. Incentives for agri-tourism
7. Greenway for a green park
8. Reforestation interventions in degraded areas
9. Hilly lakes
10. Electric bus connections between Camerino and Foligno, Ascoli Piceno, and Ancona

Part 05: Discussion of results and conclusions

5.1 Discussion of results

Returning to the research question proposed in this work, the discussion focuses on the usefulness of participatory urban design as a tool for preparing citizens and administrations to enhance resilience to natural disasters from a multi-hazard perspective. This is based on the assumption that transformative resilience regards post-disaster recovery as an opportunity for development, revitalizing the local economy and improving livelihoods and living conditions. The possibility of equipping citizens with a tool that enables active and informed participation aligns with Article 118 of the Italian Constitution: "The State, Regions, Metropolitan Cities, Provinces, and Municipalities promote the autonomous initiatives of citizens, both individually and collectively, in carrying out activities of general interest, based on the principle of subsidiarity." This principle is expressed through communication and, above all, collaboration between public authorities and citizens in pursuit of a shared goal. Traditional tools for enabling such dialogue have proven insufficient when faced with the new challenges of integrating perspectives on disaster resilience, climate change adaptation, and sustainable development as interconnected dimensions.

The theme of citizen participation in decision-making processes is also a central point in the 2030 Agenda: “By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated, and sustainable human settlement planning and management in all countries” (Target 11.3). Imagining development pathways through scenario planning gives citizens an active role in shaping the future, allowing policies and design proposals to be analyzed, discussed, and negotiated among representatives of various sectors of society on equal terms. This mode of negotiation, where all proposals are presented on the same platform with equal weight, ensures representativeness and voice - constituting a form of empowerment, especially for marginalized sectors of society.

The main objective of this thesis was to strengthen the adaptive capacity and resilience of territories and communities through participatory urban planning, promoting civic preparedness and supporting informed decision-making by public authorities. It is believed that this objective was successfully achieved. The proposals incorporated the paradigm shift proposed by transformative resilience, while also addressing climate change adaptation and more sustainable development rooted in the productive and cultural specificities of the territory. The participatory experience enhanced preparedness by increasing knowledge of local risks and specific territorial features through the interaction of diverse professional perspectives and social viewpoints. Informed decision-making processes allow the formation of new internal decision-making systems within specific groups, which is beneficial in expediting responses and mobilizing the population in the event of new emergencies or during the reconstruction phase, improving access to the overall governance system.

Popular engagement yielded tangible results, and some participants initiated new participatory processes inspired by the applied methodology. One such initiative was the Erasmus+ proposal titled *Geo-Design: Integrating Cultural Heritage and Sustainable Development through Interdisciplinary Research Education*. The creation or activation of associations and community networks within the participatory process, the development of collective norms, and the strengthening of trust play an essential role in the recovery process. These functions—core elements of social capital - enable communities to access social and economic resources through bonding, bridging, and linking relationships, with the latter being particularly important in improving the economic environment, reducing livelihood vulnerabilities, and fostering sustainable development.

The feasibility of implementing the proposed methodology in an online format - as demonstrated in the experience of Cagliari - helps overcome constraints imposed by certain disasters, such as the COVID-19 pandemic, and also enables the development of decision-making experiences among different groups and associations. In the case of Camerino, local associations that were active before 2016 did not play a significant role during the emergency or recovery periods. According to members of these associations, this lack of action was due to the destruction of their headquarters - all located in the historic center - and the displacement of many community leaders and members to other areas of the territory. This limitation might have been overcome had the associations been familiar with alternative organizational formats and decision-making systems.

Furthermore, the tool was expected to generate scenarios that fostered horizontal integration across disciplines and governmental sectors, promoting data sharing and institutional coordination. The gathering of experts from diverse fields to provide technical guidance and explanations regarding each proposal promoted transparency, reduced conflict, increased knowledge, and enhanced the legitimacy of outcomes, strengthening trust in public authorities and leadership. Additionally, the design synthesis resulting from the process provided an overall picture of community needs and enabled horizontal integration between different technical sectors within a single administration. This helped resolve intersectoral conflicts, avoided redundancy, and reduced public spending. The traditional knowledge contributed by a diverse group of representatives from across society, and their early-stage participation in the design process, allowed for a broader and more varied vision of development paths. This widened perspectives and produced unexpected insights unlikely to emerge from sector-specific planning alone. As one participant summarized: “As an architect, I could never have imagined ending up proposing a pig farm as a development solution, as happened in the final project.” A reductionist education model and the tendency to operate within the same professional circles often lead to unconscious pre-defined planning models and stylistic biases. Thinking outside the box becomes difficult when one's entire network consists of peers from the same discipline.

The simple overlay of different risk maps and the pre-assessment of high-risk areas foster multi-hazard thinking and help address physical risks more comprehensively - unlike most public sector projects, which tend to treat each hazard separately. The evaluation maps consolidate this information and convey it to the public in an intuitive format.

The evaluation maps function as a powerful tool for translating technical language into accessible visual content. Even if the rationale behind the color-coded feasibility zones (green, yellow, red) is not fully understood within the limited timeframe of the workshop, the maps serve as a starting point for generating and discussing proposals and provide the initial input needed for collective reflection. The possibility of accessing processed geographic data translated into clear and actionable information (assessment maps) enabled citizens not only to express their ideas effectively, but also to construct proposals that align with the territorial, economic, political, and regulatory features of the context. According to participants, the evaluation maps were instrumental in supporting the development of project proposals.

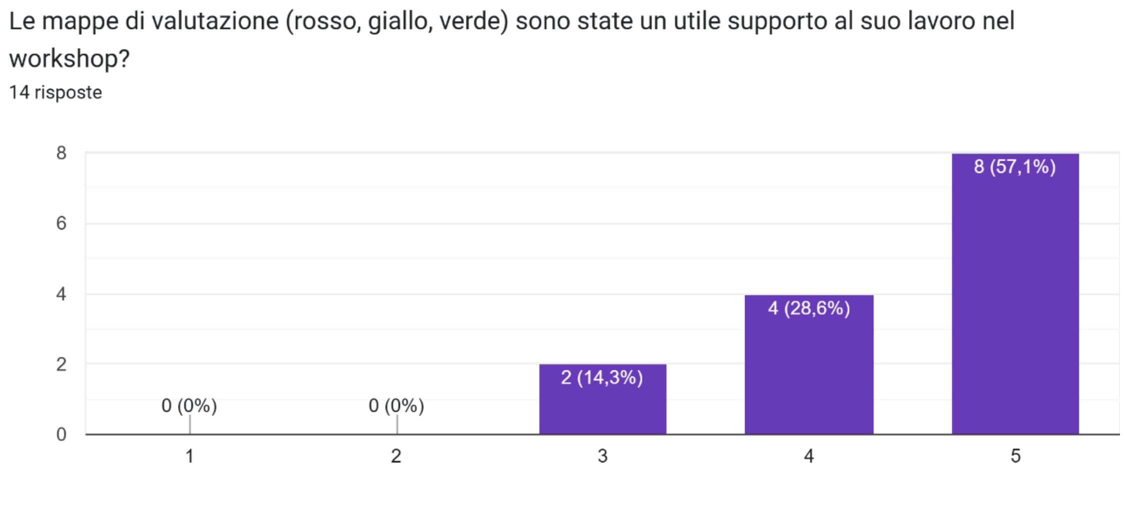

Figure 99: Result of the questionnaire: support provided by the evaluation maps. Source: Author.

Nevertheless, some participants did not fully take them into account, highlighting discrepancies between the technical study and the lived experience of the territory.

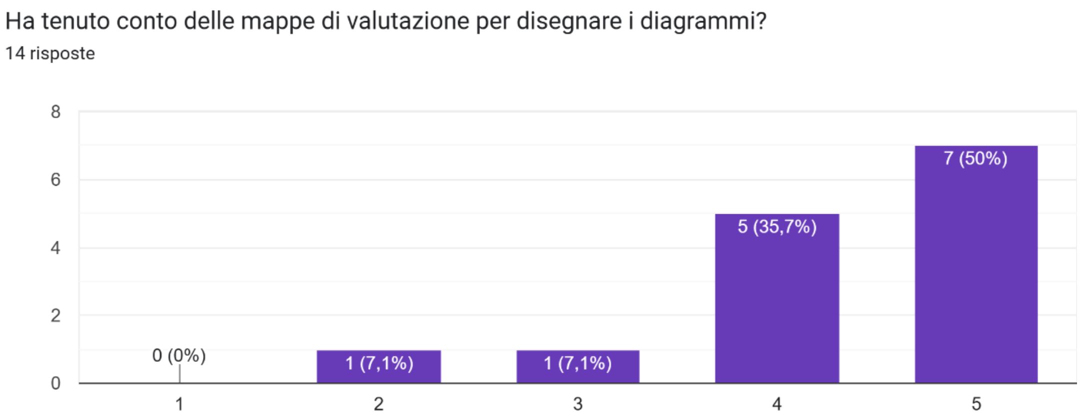

Figure 100: Result of the questionnaire: use of the evaluation maps. Source: Author

During the Geodesign workshop, participants engaged in collective reflection and experimentation with a new tool that enabled them to translate their ideas about the future development of their territory into graphic form. Through this process, they identified local challenges and issues while also proposing potential solutions. The learning process was activated from the very first session, in which citizens were introduced to system-specific data sheets containing assessment maps. This experience fostered reciprocal learning: while citizens became acquainted with graphic tools for territorial representation, technical experts gained access to valuable experiential insights offered by the local community.

As the workshop progressed, the communication dynamic gradually shifted from a predominantly verbal mode to a graphic one. Participants quickly familiarized themselves with the Geodesignhub platform, which proved intuitive and accessible. This enabled inclusive participation, particularly for individuals who, due to sociocultural background or personal disposition, might have struggled to express and share ideas using conventional formats. The clarity and simplicity of the shared materials not only disseminated technical knowledge about the local area but also reinforced participants' sense of understanding and agency. The standardized base maps provided a structure that allowed even those unfamiliar with urban design language to contribute meaningfully. As one participant noted, "I wouldn't have been able to express my ideas without a tool like this."

The general opinion among participants was that the tool functioned effectively for its intended purpose, facilitating the visualization and negotiation of proposals in a short period of time. According to them, the objective of strengthening resilience was achieved, and their knowledge—both of the study area and of disaster resilience—was significantly expanded. The application of the methodology to the case study confirmed the feasibility of using GIS-based language to communicate complex ideas in a simple and accessible manner. The GeoDesignHub platform was positively evaluated both as a co-design tool and as a valuable aid in negotiation processes.

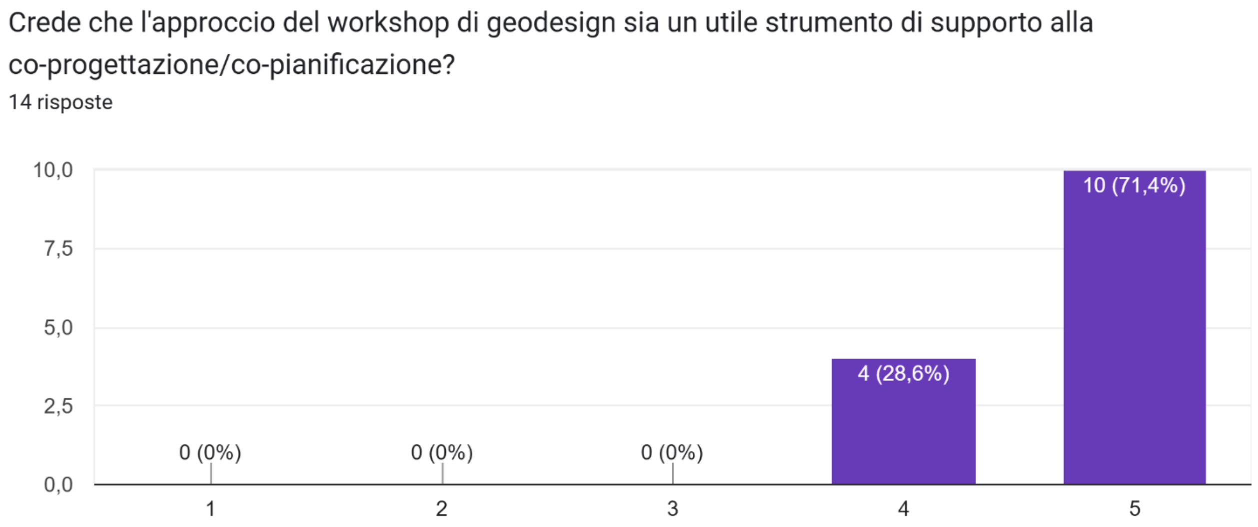

Figure 101: Result of the questionnaire: usefulness of geodesign for co-design. Source: Author

The evaluation highlights the usefulness of the assessment map as a reference framework for the planning process, supporting the hypothesis that visualization plays a crucial role in decision-making. Despite the simplified design of certain elements - such as the proposed new roads connecting Camerino to nearby service centers - most of the projects were developed in green areas. Similarly, the presentation of the reference framework outlined in the assessment model (Appendix B) proved valuable, as its guiding principles were reflected in the proposals across all systems.

However, the study of social vulnerabilities could have been explored more extensively, possibly through a dedicated session focused solely on the social and economic aspects of resilience. While the social vulnerability maps were considered in the technical work - influencing the construction of the assessment maps and shaping specific resilience strategies for the study area - they were not directly integrated into the participatory experience. Likewise, the adopted methodology lacks a more developed economic perspective, which could benefit from the integration between urban planning and fields such as economic sociology, economic geography, or urban economics.

Initially, the case study aimed to analyze the entire Central Italy earthquake crater, encompassing four regions - Marche, Abruzzo, Lazio, and Umbria. However, after preliminary investigations into the availability of georeferenced data, it became evident that such an approach was unfeasible. Despite the efforts of the INSPIRE platform, local data remain scarce and difficult to access. Moreover, there is no standardization among the datasets from the different regions, which made the proposed analysis of the entire crater impracticable. The only data consistently and homogeneously available across all four regions were risk assessments provided by national agencies. The autonomy of each region, combined with the absence of a centralized government coordinating policies and expectations, has resulted in a fragmented landscape of policies, practices, and databases. This fragmentation not only hinders national-level comparisons needed for equitable resource allocation in the most vulnerable areas but also complicates interregional cooperation. While participatory processes have the potential to overcome the difficulties posed by data scarcity and the lack of standardized quantitative indicators by drawing on personal experience - "Experiences matter more than numbers" - they can also hinder logical reasoning when participants are confronted with large volumes of complex information.

The field survey, carried out exclusively within the city limits and focused primarily on the red zone of the historic center, may have influenced participants' initial project decisions, which predominantly concentrated on the central area. Some exceptions were observed, particularly in specific systems such as the green and blue networks, which extended toward the periphery. For this reason, mediator intervention was necessary, ultimately resulting in the identification of two distinct project scales, which remain evident in the final outcomes.

Although the group included several participants residing in Camerino - both international students and people born in the city - all participants were affiliated with the university and were familiar with digital tools and research methodologies. It is therefore essential to test the methodology in other contexts, involving actors from different age groups and sociocultural backgrounds. The workshop group included both residents and non-residents of Camerino. The non-resident participants, however, were users of the territory for work, study, leisure, social connections, or other purposes. Focusing on this group, it emerged that despite their limited knowledge of the area, they were able to formulate project ideas consistent with those of other participants. Some participants, however, reported the need for additional information and more time for review: "Avrei avuto bisogno di più tempo e di più conoscenza delle esigenze locali e del funzionamento del territorio per impostare al meglio i progetti." Despite these challenges, participants from other countries expressed their satisfaction with the experience: "Sono molto contenta di aver partecipato al Geodesign Workshop: è una vera dimostrazione di resilienza sociale all'opera! Condividerò il vostro lavoro e le vostre conoscenze ulteriormente, e oltre l'Italia."

As an academic exercise, the discussion followed a relatively flexible structure. However, negotiation processes involving conflicting interests may represent a significant challenge for building consensus around the proposed ideas. Nonetheless, the final scenario represents not only a clear reflection of the participants' aspirations, but also an informed decision-making process regarding project choices - including those that were rejected during the democratic process. The tool simultaneously ensures equitable representation of all voices and provides an equal voting mechanism for all proposals, thus promoting the distribution of responsibilities and contributing to the mitigation of political conflicts.

The research experience thus far does not replace the need for practical experimentation beyond the university setting. The university should be understood as a mediator between the aspirations of the population and the implementation capacities of public authorities.

5.2 Criticisms encountered

A particular reflection by the author (who allowed herself a brief first-person consideration) concerns the impact of the unpredictability of natural disasters. The first challenge encountered in this research was the delayed start of the project due to the closure of intercontinental borders as a containment measure against the spread of COVID-19. The cascade of events triggered by the pandemic aligns with the notion of a globally interconnected risk society, in which the effects of a crisis originating far beyond national borders are felt equally - or unequally, from another perspective - at the local level. Likewise, the situation mirrored the theory of uncertainty, highlighting our widespread unpreparedness, across nearly all spheres of public and private life, to cope with unknown threats.

The research was initially conducted remotely, using experimental communication technologies characteristic of that period. The initial objective was to understand how to navigate the uncertainty of prolonged confinement, recover from economic losses, and address the pandemic's impact on the physical health of the elderly and the mental health of younger populations. As such, the first year of investigation was dedicated to understanding the pandemic and, in a somewhat ironic tone, attempting to forecast the future. As the health crisis was brought under control and life gradually returned to a certain degree of normality, the thesis assumed a more consolidated direction within the academic domain.

Throughout the development of this work, several challenges were identified, revealing both theoretical and practical limitations. First, the application of the REMAP methodology faced difficulties related to data collection and use. Despite significant advancements achieved through the INSPIRE initiative in establishing territorial information systems, government transparency did not always reflect the full potential of these systems. Many regions still rely on limited territorial databases, and several municipalities either do not provide access to existing data or impose barriers to data retrieval. Furthermore, certain types of spatial data require advanced technologies for production, which hinders their generation or results in the creation of paid platforms for data sharing.

The lack of standardization in regional and municipal indicators, combined with the scarcity of data in remote areas such as central Italy, compromised the accuracy of vulnerability assessments. Initially, the study area for this project encompassed the entire central Italy earthquake crater, but it had to be reduced to a single region due to the complete incompatibility of datasets across the four regions involved - an obstacle that made it unfeasible to complete the study within a three-year timeframe. This further emphasizes the broader issue of establishing resilience indicators. While defining a common resilience index is already challenging due to conceptual ambiguity and multidisciplinarity, it is further complicated by the lack of available data, especially in less developed countries and marginalized areas of more developed nations. The scarcity of accessible data, along with insufficient data sharing and analysis for emergency planning and recovery, remains a critical obstacle to effective risk monitoring and understanding. It also undermines comparative vulnerability analysis between locations, leading to unequal resource distribution and policies that target the wrong priorities.

Additionally, the complexity of participatory engagement and the high number of concurrent projects addressing similar themes in the city of Camerino hindered the participation of multiple stakeholders, especially representatives of governmental bodies and the general population. As a result, despite its highly interdisciplinary nature, the final output of the research retained a predominantly academic character. Another factor possibly contributing to the predominance of university-affiliated participants was the scheduling of the workshop, which took place on two consecutive weekdays, thus excluding individuals unable to take time off work. The target audience may have been more diverse had the workshop been held on weekends. Moreover, holding it on two consecutive Saturdays could have helped participants dedicate more time to developing accurate proposals, although this may have resulted in discontinuity - an issue that did occur during the technical visit, in which many local participants were absent. One non-resident participant noted: "*Avrei trovato utile che tutti i partecipanti, soprattutto quelli che conoscevano bene l'area di studio, avessero partecipato con continuità a tutte le attività incluso il sopralluogo*."

Another critical point was the initial concentration of proposals solely on the historic center, which required facilitator intervention to encourage proposals addressing the wider territorial scale. One possible reason for this was the impact of the field visit, which was limited to the historic center. As reported by a participant: "*Il sopralluogo ha inoltre fatto sì che la maggior parte delle proposte di intervento si concentrassero all'interno del centro storico poiché erano state viste più da vicino. è venuta meno in questo senso la visione più strategica e a scala vasta che le mappe di valutazione avrebbero consentito di svolgere, ma questo non incide sugli ottimi risultati del workshop: lo segnalo solo come punto di vista legato anche agli interessi personali di ricerca*." This reflects not only a deeper familiarity with the historic center and greater knowledge of that area, but also the likely lack of time to develop more comprehensive proposals for the broader territory.

Several critical issues should be considered in relation to the use of the GeodesignHub platform. The platform is comprehensive, intuitive, and visually accessible, but recent changes - including the removal of certain comparison tools - have limited its usefulness for evaluating proposals. Additionally, the size limit for geojson files is quite low, requiring excessive simplification of the spatial data. The data used in this study underwent extensive preprocessing, and the simplification required for platform integration led to some substantial inconsistencies. While this was not problematic within the academic setting, it could significantly compromise the level of detail required in public administration projects.

Another - entirely unforeseen - issue was the modification of the workshop schedule due to the platform's malfunction at the end of the first day. This malfunction was caused by a global incident affecting Windows devices on July 19, 2024, described as a cyber blackout. As a result, the technical visit to the historic center was moved forward, and the platform tutorial was postponed to the following day. Despite an earlier start, this rescheduling reduced the time available for presenting proposals. Given the participants' high level of digital literacy, the issue was overcome, but it should be considered in future projects depending on the target audience. It is also important to provide digital support to include participants from different age groups (young people and older adults) and education levels. This was a limiting factor in this research project. The inclusion of the workshop in the Better Life BootCamp narrowed the target audience to those affiliated with academic studies. Consequently, there were important limitations in terms of diversity across age, gender, and educational background.

5.3 Review and redefinition of methodology

The research enabled a thorough review and refinement of the REMAP methodology, highlighting its flexibility and applicability in practical implementation settings. Based on the identified critiques, adjustments were made to improve data integration and enhance the efficiency of the participatory process. The introduction of more intuitive visual tools - such as GIS-based interactive maps - proved essential in engaging participants and facilitating the understanding of proposed scenarios.

Furthermore, the need to adapt the methodology to different scales of application was identified. Although the case study was conceived with a regional planning approach, the technical visit focused exclusively on the city of Camerino, and the emphasis on the historic center - either due to the selected itinerary or the interests and prior experiences of the participants - led to some confusion regarding the spatial boundaries of the proposed projects. Initially, the proposals were concentrated within the urban limits, requiring facilitator intervention to encourage a broader territorial perspective. It is considered that the methodology can be adjusted both to larger urban contexts and to more specific settings, depending on whether the focus is national, regional, or local. However, defining the scale of application in the initial stages - particularly given the challenges of data access and the lack of standardization - should be one of the first steps of the process.

A critical aspect of the research was the integration of multiple hazards into a coherent framework. Although the methodology was designed to address complexity, the need to simplify it to facilitate community participation and its implementation in digital platforms generated tensions between technical precision and accessibility. The choice of the GeodesignHub platform proved effective for proposal negotiation and comparison but revealed limitations in terms of the volume and scale of data it could process. As a result, a substantial simplification of the assessment model was necessary. While this did not constitute a major limitation in the academic setting, it may pose challenges in public administration projects, where a higher level of detail is typically required.

Another significant consideration is the issue of timing. In this study, the community was invited to participate only after the assessment model had already been developed. The initial stages - the representation model and process model - were elaborated solely from an academic perspective, with contributions from stakeholders involved in other university projects. Engaging the population from the early phases could improve the understanding of the project's objectives and the constraints of the area under study. Moreover, traditional knowledge and citizen science practices could contribute to updating the database through tools such as OpenStreetMap or community-based mapping initiatives. The applicability of the methodology in municipalities lacking academic studies or digital territorial data must also be considered, since the availability and representativeness of data directly affect the implementation timeline of resilient urban plans and the performance of participatory processes. Some participants - particularly those not residing in Camerino - reported the need for additional reference materials, such as design proposals prepared by the local administration and administrative documents like the *Piano Strategico* and *Piano Spaziale*. Some of these documents were made available on the shared StoryMaps platform. It is believed that difficulties in accessing or understanding the materials were due to the limited time allocated for reviewing the content. It is therefore considered important to allow for a longer interval between participatory phases to ensure adequate engagement with the background materials, or to include an additional day in the schedule specifically for the presentation of these materials. In general, the time required for meaningful participation should be re-evaluated. The results obtained over just two days of workshops were sufficient for an academic assessment of the methodology and for the construction of a preliminary synthesis scenario to guide urban planning professionals. However, a longer interval between the presentation of the first three models - representation, process, and assessment - and the start of the design proposals phase may be crucial to a better understanding of the study area, provided that the material remains accessible for consultation. An interval of 7 to 15 days is recommended, as it would allow for a deeper analysis without the risk of information being forgotten, while also ensuring that the overall duration of the participatory process does not become excessive, which could lead to participant disengagement.

It is evident that the participatory process does not end with the delivery of the synthesis scenario. The effectiveness of the REMAP method depends on continuous dialogue between public administrations, urban planning professionals, and the local community, in order to translate the co-designed synthesis into an urban project and re-present it to the community for further integration, modification, and negotiation. Likewise, public authorities must be equipped to communicate the entire process transparently - from the initial formulation of proposals to the completion of public works.

5.4 Future research paths

The research opens promising avenues for future studies, particularly regarding the expansion and refinement of the REMAP methodology. One of the most relevant directions involves the integration of real-time climate data and the use of artificial intelligence to forecast complex scenarios, enabling a more dynamic and adaptive approach to territorial resilience assessment. Furthermore, the development of new databases - including satellite imagery and integration with remote sensing techniques - could facilitate data collection and continuous monitoring of resilience levels in the communities under analysis.

Another key area for exploration concerns the extension of the methodology to long-term studies, allowing for the monitoring of the impacts of resilience policies over time. This approach would make it possible to identify patterns of territorial transformation and to assess the effectiveness of implemented strategies, contributing to methodological refinement and improvements in participatory practices.

The application of the REMAP methodology in international contexts also represents a promising field of research. Considering different cultures, institutional frameworks, and socio-economic conditions would allow for an evaluation of the adaptability of the approach and its applicability in diverse scenarios, including specific challenges such as desertification, climate-induced migration, and pandemic crises.

Finally, a critical area of research involves incorporating a more consistent economic perspective and integrating principles of environmental justice and social equity into participatory processes. This would ensure the inclusion of historically marginalized voices in decision-making related to resilient urban planning, thereby strengthening the inclusive and democratic dimension of territorial governance.

It is essential that the methodology and tool developed be tested beyond the academic sphere to validate their effectiveness. Nevertheless, the university is envisioned as a key mediator in the negotiation between public authorities and communities, ensuring impartiality, democratic engagement, and transparency in both processes and data. The creation of a network of universities is proposed, aimed at establishing standardized pathways, resilience measurement systems, and shared databases, thus overcoming current limitations related to data unavailability, restricted access, and the lack of interregional interoperability.

5.5 Conclusions

The research developed within the scope of this thesis aimed primarily to assess the potential of participatory urban planning as a means to enhance resilience to multiple natural disasters, with a focus on its transformative dimension. Through the creation and practical evaluation of the REMAP methodology, the study sought to develop a support tool for co-design and informed decision-making, capable of simplifying and bridging technical language and local knowledge, while guiding the negotiation of proposals. The application of the methodology to the case of Camerino demonstrated the effectiveness of structured participatory processes in expanding territorial knowledge, fostering civic engagement, and integrating multiple perspectives into the decision-making process. The use of assessment maps based on georeferenced data, translated into accessible language, enabled clearer communication between experts and citizens, facilitating the understanding of local challenges and opportunities and of both present and future intervention strategies through the construction of development scenarios.

The experience confirmed that digital co-design platforms such as GeodesignHub can support the negotiation of scenarios among different actors, contributing to the strengthening of a culture of participation and to the democratization of urban planning - albeit with some limitations regarding the format of the proposed ideas. Although participation was concentrated among individuals with ties to the academic environment, the results indicate the feasibility of replicating the methodology in diverse contexts, provided it is adapted to local specificities. The workshops revealed that engaging the population in the scenario-building phase contributes to strengthening local adaptive and response capacities, as well as to identifying territorial priorities that are better aligned with community needs. This, in turn, enhances long-term social capital and opens new pathways for the operationalization of existing networks. Furthermore, the interdisciplinary nature of the methodology encouraged cooperation between technical and administrative sectors, promoting greater institutional integration.

Among the challenges observed were the difficulty in accessing standardized territorial data, limited time for proposal development, and a lack of diversity among participants. These aspects reinforce the importance of adjusting the methodology to the available resources, the time required for each phase of the process, and the target audience of each implementation. The experience also highlighted the importance of involving participants from the early stages of the process and of integrating social and economic data, particularly in areas affected by structural vulnerabilities. To ensure greater effectiveness, it is recommended that the outcomes of participatory processes be formally incorporated into public policies, and that continuous dialogue be maintained between local administrations and communities, along with the implementation of the selected proposals.

Nonetheless, the findings suggest that while significant outcomes were achieved at the local level in terms of disaster preparedness and the enhancement of community and territorial resilience, the challenge extends beyond localized efforts. The interconnected nature of risks across scales calls for a systemic perspective, both temporally and spatially, requiring a coordinated governance approach across horizontal and vertical levels. Governance implies political integration among all sectors involved in urban and territorial planning, as well as among social actors in a horizontal manner, aligning agendas particularly in the fields of disaster resilience, sustainable development, and climate adaptation. Such integration avoids duplication of efforts and inefficient use of social and financial capital. The formulation of a unified long-term proposal, to be implemented in stages, must transcend political divisions and electoral cycles. This proposal should guarantee equitable participation across all sectors of society and promote fair development.

Likewise, it is necessary to centralize strategic planning at national and regional levels with the aim of creating standardized databases and enabling comparative resilience assessments. This would facilitate resource allocation aimed at reducing inequalities, offering all municipalities equal opportunities for transformation. Higher levels of government must also support local levels by providing institutional capacity and resources for disaster management and resilience planning. Regional, national, and international funding should prioritize the most vulnerable areas, rather than being disproportionately allocated to large metropolitan centers, as was the case with the 100 Resilient Cities initiative. Moreover, there is a need to balance investments between reactive infrastructure and long-term preventive measures. This perspective transcends public and budgetary spheres, promoting a transformative - rather than merely reactive - approach in future scientific research. Addressing the structural causes of vulnerabilities and risks must take precedence over measures that merely perpetuate the status quo.

Public-private partnerships, combined with the technical expertise of universities, should support resilience assessment processes, especially in municipalities with greater social and economic vulnerabilities, thereby strengthening both social and financial capital. For this reason, the creation of inter-university networks is essential for the standardization of indicators, collaborative data construction, and the consolidation of democratic, inclusive, and transparent participatory practices.

The tool presents global relevance, with potential for adaptation to different territorial contexts exposed to multiple risks, such as coastal regions threatened by climate change or rapidly expanding urban areas. Its flexibility allows the integration of participatory processes and is particularly useful for local administrations and non-governmental organizations promoting resilience in an inclusive and democratic manner. It can also be used to assess proposals already developed by public authorities, private entities, or citizen associations. Importantly, its application is not limited to a single governance model: the methodology can be adopted in both top-down approaches, guided by centralized policies, and bottom-up initiatives promoted by communities and local actors. However, the participation of the academic community is recommended as part of the technical committee for resilience assessment and as an impartial mediator in participatory processes.

The REMAP tool, tested in the academic context of Camerino, demonstrated the ability to construct resilient scenarios at both urban and territorial scales, within the context of the Macerata earthquake crater. According to the evaluation questionnaire (Appendix C), participants agreed that the tool achieved its goal of increasing disaster knowledge and strengthening territorial resilience. Among the aspects to be improved is the need for more comprehensive field surveys and more time for analyzing the information available on the study area. Although most requested materials were available, difficulties in data visualization may have occurred due to the limited time allocated for content review. The methodology proposed the inclusion of additional meetings focused on territorial recognition and technical material review, with adequate intervals between these stages. The vast majority (97%) of participants considered that systemic planning is more effective than isolated project-based approaches. All participants expressed satisfaction with the final synthesis (on a scale from 1 to 5, with 1 being the lowest and 5 the highest: 28.6% gave a score of 4, and 71.4% gave a score of 5). According to the same questionnaire, participants reported a better understanding of the study area after the workshop, emphasizing the usefulness of the tool in facilitating collaboration among different stakeholders and supporting co-design processes.

Based on the results obtained, the REMAP methodology is considered a relevant contribution to urban planning and decision-making processes aimed at enhancing resilience to multiple disasters. Its application in international contexts, the expansion of its databases, and its integration with emerging technologies such as artificial intelligence and remote sensing represent promising directions for its future development.

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Abbreviations

100RC: 100 Resilient Cities

ABM: Agent-Based Modeling

ACCCRN: Asian Cities Climate Change Resilience Network

A-GI: Active Geoinformation

AHP: Analytic Hierarchy Process

AI: Artificial Intelligence

ANNs: Artificial Neural Networks

ARIMA: AutoRegressive Integrated Moving Average

BASP: Bologna Adaptation Strategy Plan

CAPI: Computer Assisted Personal Interviewing

CAWI: Computer Assisted Web Interviewing

CM: Change Model

CRED: Center for Research on the Epidemiology of Disasters

CSES: Complex Social-Ecological Systems

DM: Decision Model

DROP: Disaster Resilience of Place

DRR: Disaster Risk Reduction

DSR: Design Science Research

EEA: European Environment Agency

EM: Evaluation Model

EM-DAT: Emergency Events Database

FA: Factor Analysis

FIU: Fondazione per l'Innovazone Urbana

GARCH: Generalized Autoregressive Conditional Heteroskedasticity

GD: GeoDesign

GDF: GeoDesign Framework

GDI: Geospatial Data Infrastructure

GIS: Geographic Information System

GRAF: Global Risk Assessment Framework

GSSI: Gran Sasso Science Institute

HDI: HUman Development Index

HIPS: Hazard Information Profiles

IDNDR: International Decade for Natural Disaster Reduction

IM: Impact Model

INGV: Istituto Nazionale di Geofisica e Vulcanologia

INFN: Istuto Nazionale di Fisica Nucleare

IoT: Internet of Things

IPCC: Intergovernmental Panel on Climate Change

ISTAT: Istituto Nazionale di Statistica

JRC: Joint Research Centre

KPI: Key Performance Indicator

MCDM: Multi-criteria Decision Making

NGO: Non-Governmental Organizations

PCA: Principal Component Analysis

PGIS: Participatory Geographic Information Systems

PM: Process Model

PNRR: Piano Nazionale di Ripresa e Resilienza

POC: Piano Operativo Comunale

PROMETHEE: Preference Ranking Organization Method for Enrichment Evaluations

PSC: Piano Strutturale Comunale

Q-GIS: Quantum Geographic Information System

REDI: Reducing Risks of Natural Disasters

REMAP: Resilient and Engaged Multi-hazard Assessment for Planning

RM: Representation Model

RUE: Regolamento Urbanistico Edilizio

SAE: Soluzioni Abitative di Emergenza

SDGs: Sustainable Development Goals

SDI: Spatial Data Infrastructure

SDSS: Spatial Decision Support Systems

SESs: Social-ecological Systems

SMGI: Social Media Geographic Information

SNAI: Strategia Nazionale per le Aree Interne

SoVI: Social Vulnerability Index

SVI: Social Vulnerability Index

TOPSIS: Technique for Order Preference by Similarity to Ideal Solution

UNDP: United Nations Development Programme

UNDRR: United Nations Office for Disaster Risk Reduction

UNICAM: University of Camerino

UNISDR: United Nations International Strategy for Disaster Reduction

VAR: Vector Autoregression

Appendices

Apêndice A – Questionário de inscrição – Conhecendo os atores

Sezione 1 di 2

Workshop: Scenari condivisi per un futuro resiliente di Camerino

Per favore, compila questo modulo per confermare la tua partecipazione al workshop di Geodesign che si terrà c/o l'Università di Camerino il 22 e 23 luglio

Nome e Cognome *

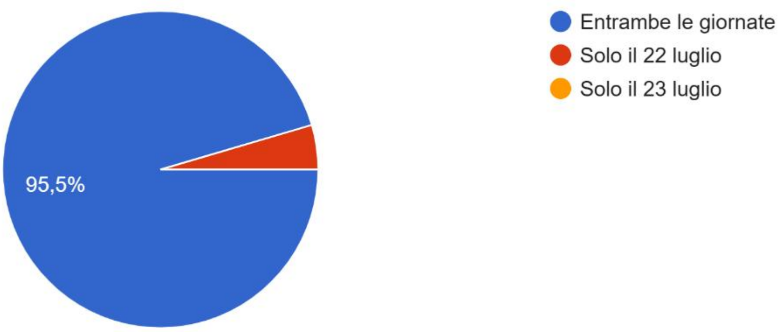
Testo risposta breve

Email *

Testo risposta breve

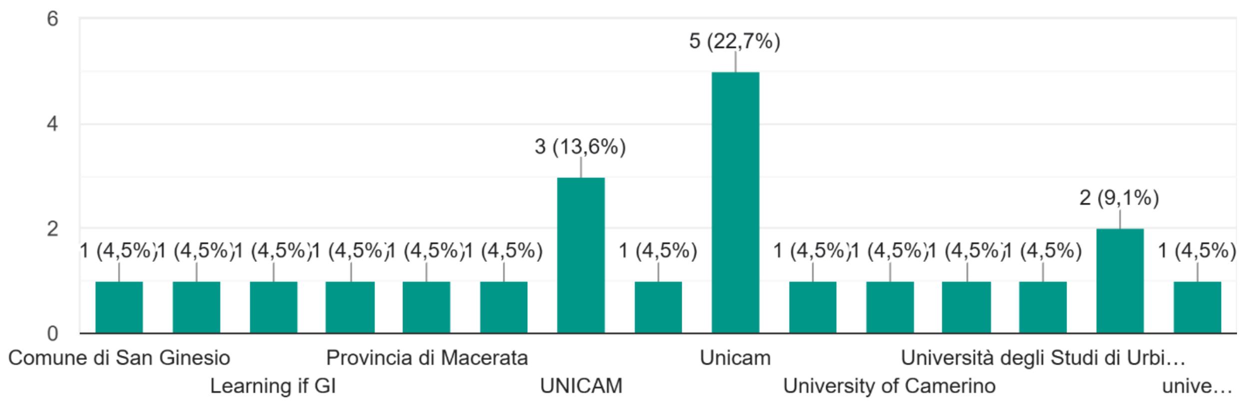
Partecipazione al workshop:

22 risposte



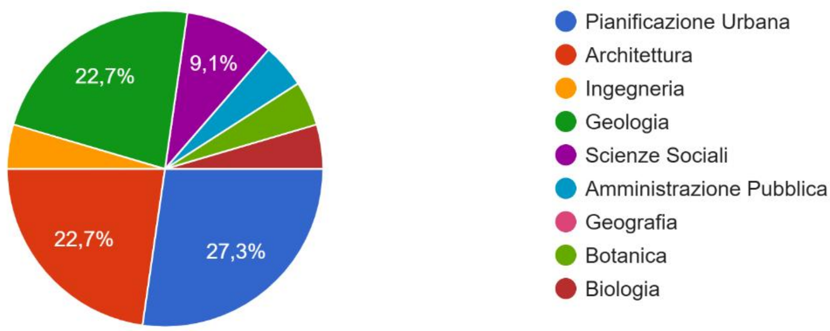
Istituzione di appartenenza

22 risposte



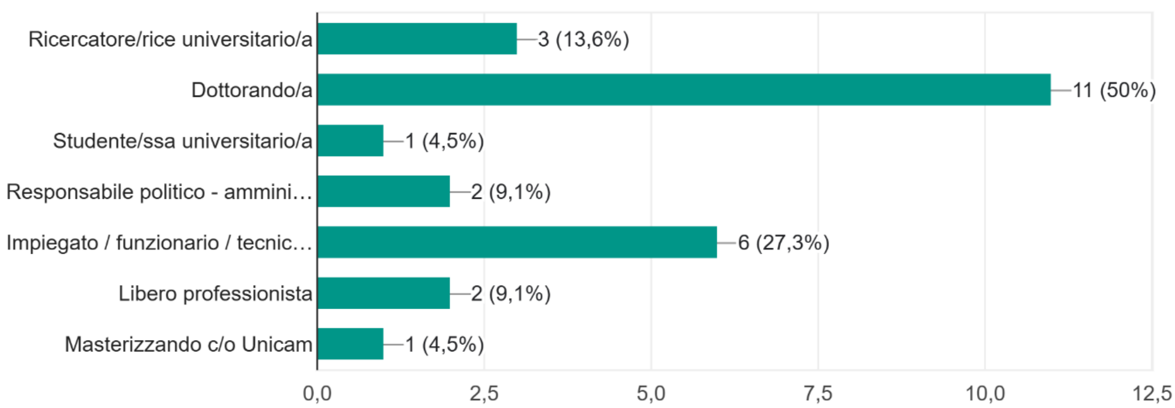
Ambito d'esperienza

22 risposte

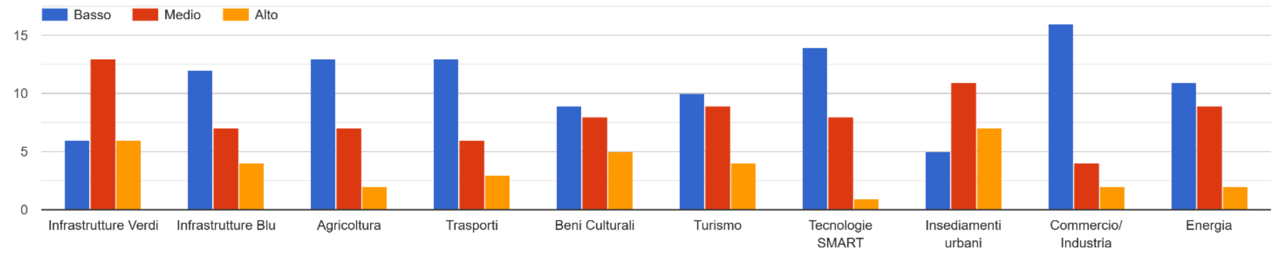


Attività lavorativa

22 risposte

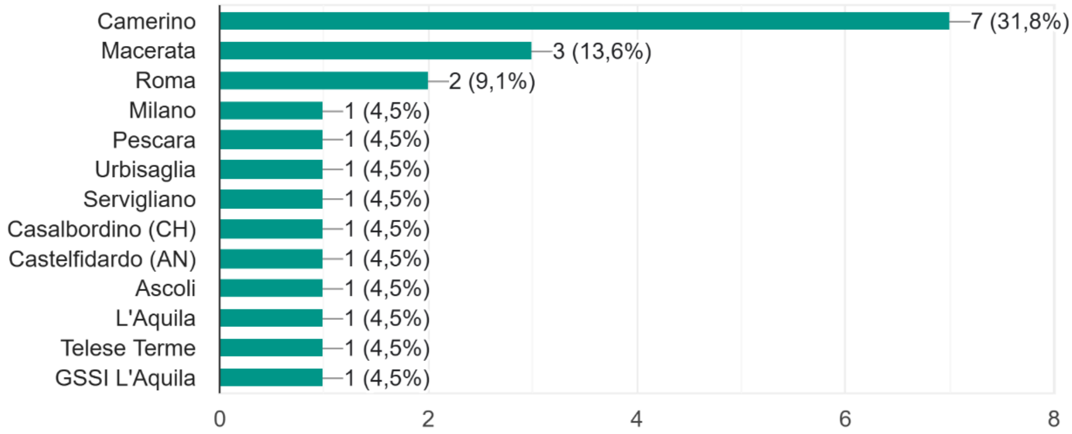


Indicare il livello di conoscenze dei seguenti argomenti



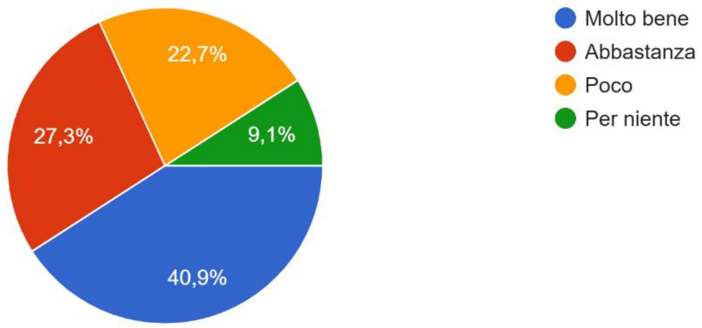
Luogo di Residenza

22 risposte



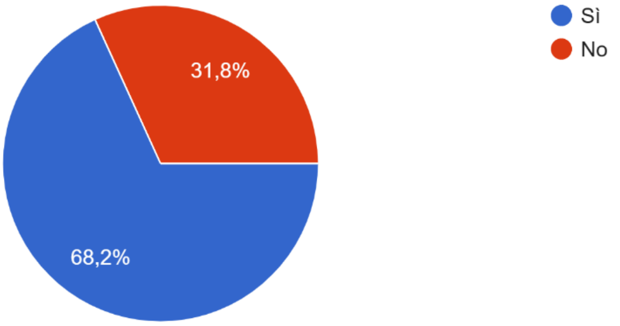
Quanto conosci la città di Camerino?

22 risposte



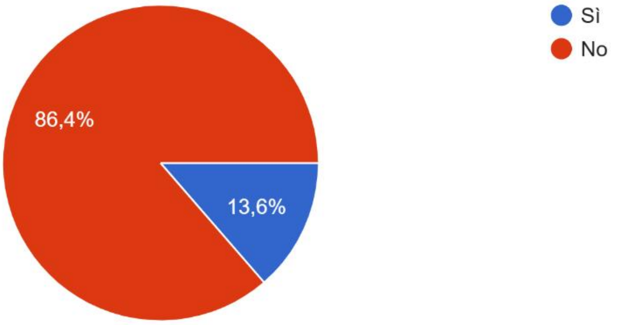
Hai esperienza in laboratori di progettazione collaborativa?

22 risposte



Hai intolleranze alimentari?

22 risposte



Sezione 2 di 2

Specifica Intolleranza Alimentare

Descrizione (facoltativa)

BETTER Life Bootcamp - Workshop: Scenari condivisi per un futuro resiliente di Camerino (22-23/07/2024)
System's Evaluation Model

Reference: Campagna, M., di Cesare, E. A., & Cocco, C. (2020). Integrating Green-Infrastructures Design in Strategic Spatial Planning with Geodesign. *Sustainability*, 12(5), 1–22.

Rationale

GREEN INFRASTRUCTURE

The green infrastructure system focuses on protecting and connecting high-quality natural areas located in urban, suburban and rural areas in order to protect biodiversity and increase nature's capacity to provide valuable ecosystem goods and services. The crater area encompasses 108 Sites of Community Interest and Natura 2000 Special Protection Areas, with the aim of ensuring the long-term survival of the most valuable and threatened local species and habitats listed in the body of the guidelines.

However, these are mountainous areas, far from population centres and difficult to access, and most urban settlements are characterised by low density and easy permeability. For this reason, many of the most densely populated areas lack public green spaces. Many areas have a high risk of flooding and landslides that must be considered, studied and resolved, especially near urban centres.

Suggested actions (projects or policies)

- Maximising ecosystem services: - New protected areas, opening of new parks and trails, new ecological corridors;
- Multifunctional agriculture;
- Use nature-based solutions to resolve landslide-prone areas;
- Creating green infrastructure for rainwater management and solving flooding problems;
- **Possible actions in settlements**: stopping land consumption, increasing green infrastructure (roads and public spaces), rain gardens, urban agriculture; urban forestation;
- **-Possible integrated actions:** Green Belt.

	Existing	Not appropriate	Capable	suitable	Feasible
classification	Is where the system is "existing" already and in a healthy state, meaning that it is feasible to remain a constraint in terms of information but not a total Constraint.	Is lowest priority for change "not appropriate" or not capable of supporting the system, meaning don't put it there, e.g., too wet or steep or unless you provide change to the basic area conditions e.g., fill in the ocean for new land, regrade the mountain, etc. (all very risky projects). This is also a constraint in terms of information.	Is low but higher priority "capable", meaning that you can place it here IF you also provide the technology and market to make it feasible, e.g., water and sewers, access roads for mechanical harvesting, etc., and the market comes	Is higher priority "suitable", meaning that the area is capable of supporting the project and it already has the appropriate technologies to support the activity taking place e.g., septic tank soil or sewers, access roads for mechanical harvesting, etc. BUT there may not yet be a market for the change.	Is the highest priority for change "feasible", meaning that it is suitable AND there is a demand or market to provide the new land use change, e.g., that someone wants to buy the product or new house (and at a profit) OR that the government wants to protect and improve an historical landscape.

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Description	• Protected natural areas • Artificial non-agricultural green areas (urban parks and sports areas)	• Artificial urbanised areas, urban, industrial and infrastructure centres	• Agricultural areas with systems of community interest, such as permanently cultivated areas or areas with autonomous or semi-autonomous development, such as non-irrigated arable land and evolving wooded vegetation or wooded areas that are not part of the REM.	• Green connection systems not connected to other green areas and areas occupied by agricultural systems with important natural spaces	• This class includes risk environments that require urgent action, such as areas at risk of landslides or flooding near urban centres or areas at risk of forest fires. • It also includes the conservation of areas of interest for the preservation of biodiversity.
Data	• REM Marche • Corine Land Cover 2008	• Corine Land Cover 2008	• Corine Land Cover 2008	• Corine Land Cover 2008 • MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • REM Marche: Sistemi di connessioni locali collegati	• MASE-Geoportale Nazionale: AIB Rischio incendi globale nei parchi nazionali • Corine Land Cover 2008 • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica • MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • REM Marche • Geoportale Regione Marche: Database dell'idrografia regionale

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Operators	• REM Marche: Aree protette: ZPS, SIC, EUAP, Natura 2000 • Corine Land Cover 1.4. Zone verdi artificiali non agricole	• Corine Land Cover 1.1. Zone urbanizzate di tipo residenziale • Corine Land Cover 1.2. Zone industriali, commerciali ed infrastrutturali	• Corine Land Cover 2.1.1. Seminativi in aree non irrigue • Corine Land Cover 2.4.2. Sistemi colturali e particellari complessi • Corine Land Cover 2.2. Colture permanenti • Corine Land Cover 2.3. Prati stabili (foraggere permanenti) • Corine Land Cover 3.2.4. Aree a vegetazione boschiva ed arbustiva in evoluzione • Corine Land Cover 3.1. Zone boscate fuori delle aree REM: aree protette, core area, sistemi di connessioni locali o stepping stone	• REM Marche: Sistemi di connessioni locali collegati • Corine Land Cover 2.4.3. Aree prevalentemente occupate da colture agrarie con presenza di spazi naturali importanti	• MASE-Geoportale Nazionale: AIB Rischio incendi globale nei parchi nazionali: Habitat a rischio • MASE-Geoportale Nazionale: AIB Rischio incendi globale nei parchi nazionali: Zone rosse prioritarie • REM Marche: Sistemi di connessioni locali non collegati • REM Marche: Stepping stone • REM Marche: Core area • Corine Land Cover 4. Zone umide • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana in Corine Land Cover 2.4.3. Aree prevalentemente occupate da colture agrarie con presenza di spazi naturali importanti • Database dell'idrografia Regionale: Fiumi (buffer 200m) • Database dell'idrografia Regionale Torrenti (buffer 100m) • MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) nelle aree Corine Land Cover 1.1. Zone urbanizzate di tipo residenziale o 1.2. Zone industriali, commerciali ed infrastrutturali • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di rischio di frana nelle aree Corine Land Cover 1.1. Zone urbanizzate di tipo residenziale o 1.2. Zone industriali, commerciali ed infrastrutturali

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Rationale	**ENERGY** This system accommodates projects aimed at the transition to a carbon-neutral economy, based on clean and renewable energies, energy storage and energy efficiency of the building stock. It aims to reduce environmentally harmful emissions and strengthen the use of smart technologies that have the capacity to integrate systems, facilitating consumer acceptance of transitions, simplifying daily activities and improving well-being, as well as facilitating management operations by governments and institutions.				
	Suggested actions (projects or policies) • Support for the implementation of biomass systems (for electricity and heat); • Supporting the implementation of solar energy systems; • Support for the implementation of wind energy systems (mini-wind power plants); • Supporting the implementation of low-enthalpy geothermal energy systems (risk/cooling); • Supporting the implementation of fuel cell integrated heat pump systems; • Support for energy efficiency in reconstruction; • Development of energy communities.				
	Existing	**Not appropriate**	**Capable**	**suitable**	**Feasible**
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Description	• Systems producing energy from renewable sources: biomass, wind, hydroelectric, solar, geothermal and heat pumps.	• Protected natural areas, productive artificial areas or areas in a state of neglect	• Artificial urbanised areas and areas at risk of landslides	• Open areas with shrub or sparse vegetation suitable for wind energy production • Agricultural areas suitable for biomass production	• Forest areas outside protected areas suitable for biomass production • Large lakes, reservoirs and rivers suitable for hydroelectric or micro-hydroelectric power generation • Stable meadows in areas suitable for wind energy production
Data	• ISTAT • Open Street Map	• Aree naturali protette: Natura 2000, ZPS, SIC, EUAP (REM Marche) • Corine Land Cover	• Corine Land Cover • PAI – MASE: Geoportale Nazionale	• Corine Land Cover • AEOLIAN – Wind Speed 125m a.g.l	• Corine Land Cover • ISTAT • Corsi d'acqua Marche – Geoportale regionale • AEOLIAN – Wind Speed 125m a.g.l
Operators	• ISTAT: Limite Comunale di Serrapetrona (eolica) • ISTAT: Lago di Fiastra (idroelettrica) • OSM: Impianti solari	• REM Marche: Aree protette: ZPS, SIC, EUAP, Natura 2000 • Corine Land Cover 1.3. Zone estrattive, cantieri, discariche e terreni artefatti e abbandonati • Corine Land Cover 4. Zone Umide • Corine Land Cover 5. Corpi Idrici • Corine Land Cover 1.4. Zone verdi artificiali non agricole	• Corine Land Cover 1.1. Zone urbanizzate di tipo residenziale • Corine Land Cover 1.2. Zone industriali, commerciali ed infrastrutturali • MASE: Geoportale Nazionale: Catalogo frane	• Corine Land Cover 3.2. Zone caratterizzate da vegetazione arbustiva e/o erbacea in combinazione con le aree AEOLIAN: Wind speed 125 m a.g.l (7-8 m/s) • Corine Land Cover 3.3. Zone aperte con vegetazione rada o assente in combinazione con le aree AEOLIAN Wind speed 125 m a.g.l (7-8 m/s) • Corine Land Cover 2. Superfici Agricole	• Corine Land Cover 3. Territori boscati e ambienti semi-naturali • Corine Land Cover 5. Corpi idrici • Fiumi di grande portata (Buffer 100m) • Corine Land Cover 2.3. Prati stabili (foraggere permanenti) in combinazione con le aree AEOLIAN Wind speed 125 m a.g.l (8-9 m/s)

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Rationale

BLUE INFRASTRUCTURE
The blue infrastructure system is characterised by ecological and anthroposocial links. The system includes projects aimed at developing hydrogeological risk mitigation operations and improving the quality of water resources and distribution infrastructure. For this reason, it focuses on protecting and connecting natural and semi-natural wetlands, rivers and coastlines in order to protect biodiversity and increase the capacity to provide saltwater and/or freshwater-related ecosystem goods and services.

Suggested actions (projects or policies)

- Green infrastructure for rainwater management and solving flooding problems;
- Development of an integrated urban green system articulated in interconnecting nodes and corridors;
- Creek Restoration & Naturescaping;
- Maintenance and reclamation of wetlands and riverbeds;
- Reducing coastal erosion;
- Renaturalisation of man-made areas;
- Containing possible pollutants in surface and groundwater;
- Promoting recreational and commercial activities related to rivers;
- Reducing losses in water networks;

	Existing	**Not appropriate**	**Capable**	**suitable**	**Feasible**
classification	Is where the system is "existing" already and in a healthy state, meaning that it is feasible to remain a constraint in terms of information but not a total Constraint.	Is lowest priority for change "not appropriate" or not capable of supporting the system, meaning don't put it there, e.g., too wet or steep or unless you provide change to the basic area conditions e.g., fill in the ocean for new land, regrade the mountain, etc. (all very risky projects). This is also a constraint in terms of information.	Is low but higher priority "capable", meaning that you can place it here IF you also provide the technology and market to make it feasible, e.g., water and sewers, access roads for mechanical harvesting, etc., and the market comes	Is higher priority "suitable", meaning that the area is capable of supporting the project and it already has the appropriate technologies to support the activity taking place e.g., septic tank soil or sewers, access roads for mechanical harvesting, etc. BUT there may not yet be a market for the change.	Is the highest priority for change "feasible", meaning that it is suitable AND there is a demand or market to provide the new land use change, e.g., that someone wants to buy the product or new house (and at a profit) OR that the government wants to protect and improve an historical landscape.

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Description	• Lakes and rivers with good water quality and purification systems	• Dry areas without probable environmental risks	• Rivers with good water quality	• Floodplain green areas with the capacity to develop green connections, but with possible flooding issues	• Landslide or flood-prone areas • Areas close to rivers (200 m) to be protected • Sewerage and drainage without treatment • Rivers with poor water quality
Data	• Corine Land Cover • ARPAM: Impianti di Depurazione	• Tutte le aree rimanenti Corine Land Cover	• ARPAM: Stato Ecologico dei Corpi Idrici	• REM (Rete Ecologica delle Marche)	• MASE-Geoportale Nazionale • Database dell'idrografia Regionale Marche • ARPAM
Operators	• Corine Land Cover 5. Corpi Idrici • ARPAM: Impianti di Depurazione - Buffer 500m	• Tutte le aree rimanenti	• ARPAM: Stato Ecologico dei Corpi Idrici (2018-2020): Buono (Buffer 100m)	• REM: Unità di paesaggio alluvionale	• MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • Database dell'idrografia Regionale: Fiumi (buffer 200m) • ARPAM: Stato Ecologico dei Corpi Idrici (2018-2020): Scarso (Buffer 100m) • ARPAM: Impianti di Depurazione: Scarico senza trattamento (Buffer 500m) • ARPAM: Impianti di Depurazione: Rete fognaria senza trattamento (Buffer 500m)

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<table>
<tr><td rowspan="2">Rationale</td><td colspan="5">TRANSPORT
The system includes projects for the realisation of infrastructures, nodes and routes for fast and soft mobility to support the flow of people and goods. The transport system in the Crater area is characterised by a considerable slowness in movement and by the difficulty in connecting the municipalities among themselves and on a supra-local scale. This situation is mainly attributable to a road network of ancient origin, influenced by morphological difficulties and the widespread fragmentation of urban settlements. The low density of these settlements results in long distances to travel and high costs for the implementation of public collective mobility systems. In addition, there is a complexity and slowness of access to essential service centres, largely resulting from the lack of connection between various public transport modes and private transport routes, a problem further exacerbated by the damage caused by the earthquake.</td></tr>
<tr><td colspan="5">Suggested actions (projects or policies)

Overall objective: to increase physical connectivity through the implementation of intelligent, sustainable and integrated mobility and transport systems

• Supporting intermodality, connecting ports, airports, railway stations and motorways with each other and with local transport (at municipal, regional, national and international level) for public and private transport;
• Strengthening the LPT by introducing multi-modal nodes connecting each municipality with each other and with the centres of tourist services and activities;
• Strengthen strategically important infrastructure by improving slow and fast connections and facilitating the connection between railway lines and public transport;
• Completion of the cycling system;
• Eco-sustainable tourism routes;
• Encouraging the use of clean energy vehicles;
• Strengthen transport infrastructure against the possibility of a natural event (earthquakes, landslides and floods) inside and outside built-up areas;
• Rehabilitating earthquake-damaged infrastructure.</td></tr>
<tr><td></td><td>Existing</td><td>Not appropriate</td><td>Capable</td><td>suitable</td><td>Feasible</td></tr>
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Description	• Existing railways • Existing cycle paths • Nationally or regionally managed roads	• Areas at risk of landslides or flooding • Protected areas, non-agricultural artificial turf areas, permanent crops, mining and dumping areas, wetlands	• Urban residential or industrial areas	• Other areas with a ground slope greater than 10%.	• Other areas with a ground slope of less than 10 per cent
Data	• Open Street Map (OSM): Ciclabili • Strati Prioritari di Interesse Nazionale" (DBPrior10k)	• Corine Land Cover • MASE – Geoportale Nazionale • REM Marche • Geoportale Regione Marche: Database dell'idrografia Regionale	• Corine Land Cover	• Copernicus Digital Elevation Model (DEM)	• Copernicus Digital Elevation Model (DEM)
Operators	• OSM: Ciclabili • Strati Prioritari di Interesse Nazionale" (DBPrior10k): Ferrovie • Strati Prioritari di Interesse Nazionale" (DBPrior10k): Strade Nazionali e Regionali	• MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • Corine Land Cover 1.4. Zone verdi artificiali non agricole • REM Marche: Aree protette: ZPS, SIC, EUAP, Natura 2000 • Corine Land Cover 4. Zone umide • Corine Land Cover 5. Corpi idrici • Corine Land Cover 2.2. Colture permanenti • Corine Land Cover 1.3. Zone estrattive, cantieri, discariche e terreni artefatti e abbandonati • Database dell'idrografia Regionale: Fiumi (buffer 200m)	• Corine Land Cover 1.1. Zone urbanizzate di tipo residenziale • Corine Land Cover 1.2. Zone industriali, commerciali ed infrastrutturali	• Areas outside the urban area and unsuitable areas (in yellow) with a slope greater than 10%.	• Areas outside the urban area and unsuitable areas (in yellow) with a slope of less than 10%.

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Rationale

AGRICULTURE

The main objective of the system is the integrated valorisation of production resources, based on creativity, tradition and local skills, connecting them to the social and cultural heritage. To exploit Italy's competitive advantage in high quality production, to promote the competitiveness of enterprises internationally by increasing the value of brands for commercial and tourism purposes (Made in Italy).

The depopulation process has also accentuated the abandonment of pastures, causing a significant contraction of livestock activities and a profound transformation in land use. In this context, agriculture takes on a dual function: producing high quality food and managing the land in line with its territorial potential. This implies adopting ways that favour the maintenance and reconstruction of soil fertility, the management of the river network and the containment of biodiversity loss resulting from agricultural development and the monopoly in the sale of seeds and chemicals by large multinational groups, through organic production models. Facilitating access to the trail network can help maintain the trails and attract new consumers to nature-based agritourism.

Suggested actions (projects or policies)

- Promoting the circular economy;
- Promote crop rotation and multiple use;
- Limiting the advance of urban centres and scattered settlement and creating an attractive landscape: maintain and create new cultivation areas in the urban/rural transition area;
- Protect culturally important cultivated areas;
- Integrating tourism in the cultivation areas through Made in Italy and the hospitality sector;
- Limiting the rural exodus.

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Descriptio n	• -	• Specially protected natural areas • Artificial Surfaces • Wetlands • Mining areas, construction sites and landfills	• Green areas at risk of landslides or flooding • Forested areas outside protected areas	• Current agricultural areas: arable land, mixed areas and permanent grassland	• Agricultural areas with permanent crops (areas of cultural prestige/importance)
Data	• -	• REM Marche • Corine Land Cover 2008	• MASE – Geoportale Nazionale: • Corine Land Cover 2008	• Corine Land Cover 2008	• Corine Land Cover 2008
Operators	• -	• REM Marche: Aree protette: ZPS, SIC, EUAP, Natura 2000 • Corine Land Cover 1. Superfici artificiali • Corine Land Cover 4. Zone umide • Corine Land Cover 1.3. Zone estrattive, cantieri, discariche	• MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • Corine Land Cover 3.1. Zone boscate	• Corine Land Cover 2.4. Zone agricole eterogenee • Corine Land Cover 2.1.1. Seminativi in aree non irrigue • Corine Land Cover 2.3. Prati stabili (foraggere permanenti)	• Corine Land Cover 2.2. Colture permanenti

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Rationale

CULTURAL HERITAGE (CULTURAL GOODS)

The system accommodates projects for the preservation and enhancement of cultural heritage, through actions for the recovery and use of works of art, museum collections, architecture and archaeological sites. It must also provide ways to maintain and support cultural activities and the recovery of works lost during the earthquake. The region has a very dispersed cultural and historical heritage and small historic villages in a state of semi-abandonment. The maintenance of museums (management and financial) presents a great challenge.

Suggested actions (projects or policies)

The objective is the creation of cultural support networks - museum networks, the definition and support of educational paths, the enhancement of tourist attractiveness and local trade.

- Linking post-earthquake reconstruction to innovative management methodologies for tourist attraction;
- IoT e ICT;
- Cultural routes - networks of villages, museums, historical architecture;
- Enhancing the value of 'Made in Italy': linking with agribusiness;
- museum networks, formed by public-private partnerships;
- interconnected sectors such as tourism and hospitality.

	Existing	Not appropriate	Capable	suitable	Feasible
classification	Is where the system is "existing" already and in a healthy state, meaning that it is feasible to remain a constraint in terms of information but not a total Constraint.	Is lowest priority for change "not appropriate" or not capable of supporting the system, meaning don't put it there, e.g., too wet or steep or unless you provide change to the basic area conditions e.g., fill in the ocean for new land, regrade the mountain, etc. (all very risky projects). This is also a constraint in terms of information.	Is low but higher priority "capable", meaning that you can place it here IF you also provide the technology and market to make it feasible, e.g., water and sewers, access roads for mechanical harvesting, etc., and the market comes	Is higher priority "suitable", meaning that the area is capable of supporting the project and it already has the appropriate technologies to support the activity taking place e.g., septic tank soil or sewers, access roads for mechanical harvesting, etc. BUT there may not yet be a market for the change.	Is the highest priority for change "feasible", meaning that it is suitable AND there is a demand or market to provide the new land use change, e.g., that someone wants to buy the product or new house (and at a profit) OR that the government wants to protect and improve an historical landscape.

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Description	• -	• Areas without cultural or natural heritage	• Areas with cultural assets with a low concentration of risks (level 4 or 5 of the sum of risks) • Areas with a low concentration of cultural heritage	• Areas with cultural assets with a medium concentration of risks (level 4 or 5 of the sum of risks) • Areas with a medium concentration of cultural heritage • The historic centre of Camerino	• Areas with cultural assets with a high concentration of risks (level 4 or 5 of the sum of risks) • Areas with a high concentration of cultural heritage • Camerino Red Zone
Data	• -	• Remaining area	• GoodPA (Open Data Regione Marche): Punti di interesse Turistico • MIBACT: Catalogo Generale dei Beni Culturali (ICCD) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana, estensione dell'area allagabile; Classificazione sismica	• Comune di Camerino: Perimetrazione "Centro Storico" • GoodPA (Open Data Regione Marche): Punti di interesse Turistico • MIBACT: Catalogo Generale dei Beni Culturali (ICCD) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana, estensione dell'area allagabile; Classificazione sismica •	• MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana, estensione dell'area allagabile; Classificazione sismica • Comune di Camerino: Perimetrazione "Zona Rossa" • GoodPA ; POI • GNA – MIBACT • GNA – Siti Archeologici • REM Marche
Operators	• -	• Area rimanente, priva di beni storici e artistici	• GoodPA (Open Data Regione Marche): Punti di interesse Turistico in aree di rischio basso (frana + terremoto + alluvione) Buffer 100m • MIBACT: Catalogo Generale dei Beni Culturali (ICCD) in aree di rischio basso (frana + terremoto + alluvione) Buffer 100m • Kernel dei punti MIBACT e POI (0,27 a 0,85)	• Comune di Camerino: Perimetrazione "Centro Storico" • GoodPA (Open Data Regione Marche): Punti di interesse Turistico in aree di rischio medio (frana + terremoto + alluvione) Buffer 100m • MIBACT: Catalogo Generale dei Beni Culturali (ICCD) in aree di rischio medio (frana + terremoto + alluvione) Buffer 100m • Kernel dei punti MIBACT e POI (0,85 a 4,56)	• MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • Comune di Camerino: Perimetrazione "Zona Rossa" • GoodPA (Open Data Regione Marche): Punti di interesse Turistico in aree di rischio alto (frana + terremoto + alluvione) Buffer 100m • MIBACT: Catalogo Generale dei Beni Culturali (ICCD) in aree di rischio alto (frana + terremoto + alluvione) Buffer 100m • GNA: Siti archeologici in aree di rischio alto (frana + terremoto + alluvione) • Kernel dos pontos MIBACT e POI (4,56 a 11,31) • REM Marche: Aree protette: ZPS, SIC, EUAP, Natura 2000

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<table>
<tr><td rowspan="2">Rationale</td><td colspan="5">TOURISM
This system represents the turning point for all other systems, assuming a crucial role in revitalising the region's territories and communities, addressing fundamental aspects related to attractiveness, economic, social, environmental and identity aspects. It aims to guarantee and optimise the tourism offer, emphasising the redevelopment not only of cultural and historical assets, but above all of environmental aspects that have hitherto been undervalued and underused. The main challenge for tourism in the region lies in the spatial spread of assets and the difficulties in maintaining and managing them, resulting from limited financial resources and a low level of labour skills. It is hoped that projects will focus on improving the qualification of staff and creating networks for the management and promotion of local culture, both for historical and cultural assets, such as museums and religious heritage, and especially for the promotion of nature and 'Made in Italy' tourism.</td></tr>
<tr><td colspan="5">Suggested actions (projects or policies)

The objective is the creation of cultural support networks - museum networks, the definition and support of educational routes, the enhancement of tourist attractiveness and local trade.
Linking post-earthquake reconstruction to innovative management methodologies for tourist attraction;
IoT e ICT ;
Cultural routes - networks of villages, museums, historical architecture;
Enhancing the value of 'Made in Italy': linking with agribusiness;
museum networks, formed by public-private partnerships;
interconnected sectors such as tourism and hospitality;
Development of communication systems (pre-trip and stay);
Development of cultural, environmental, catering and hotel services;
Diversification of the range of products and services;
Increasing the offer of nature-based tourism services;
High levels of accessibility and connectivity.</td></tr>
<tr><td></td><td>Existing</td><td>Not appropriate</td><td>Capable</td><td>suitable</td><td>Feasible</td></tr>
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Description	• Existing offer of paths connecting cultural or natural heritage • Cultural points of interest served by hotel services and reception centres	• Areas without cultural and natural goods • Areas at risk of landslides or flooding • Agricultural areas (non-value crops) • Forest areas	• Cultural heritage areas with reception facilities at a distance of at least 1 km, but without reception centres at a distance of 3 km.	• Areas with cultural heritage without hotel services at a distance of at least 1 km, but with reception centres at a distance of 3 km. • Under-served or little-known tourist network • Historic sites without protection by public heritage agencies	• Areas with cultural goods without reception facilities at a distance of at least 1 km and without reception centres at a distance of 3 km. • Fine Crops • Urban areas of prestige (historic villages or urban areas served by cultural heritage) • Musal path defined by ISTAT in 2018 • Protected natural areas
Data	• All Trails: Rete sentieristica Provincia di Macerata • GoodPA (Open Data Regione Marche): Punti di interesse Turistico • MIBACT: Catalogo Generale dei Beni Culturali (ICCD) • Regione Marche: Strutture ricettive	• MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • Corine Land Cover	• GoodPA (Open Data Regione Marche): Punti di interesse Turistico • MIBACT: Catalogo Generale dei Beni Culturali (ICCD) • Regione Marche: Strutture ricettive	• Open Street Map: Rete sentieristica • GoodPA (Open Data Regione Marche): Punti di interesse Turistico • MIBACT: Catalogo Generale dei Beni Culturali (ICCD) • Regione Marche: Strutture ricettive	• Corine Land Cover 2008 • ISTAT: Percorsi museali in Italia nel 2018 • GoodPA (Open Data Regione Marche): Punti di interesse Turistico • MIBACT: Catalogo Generale dei Beni Culturali (ICCD) • REM Marche • Regione Marche: Strutture ricettive
Operators	• All Trails: Rete sentieristica (Buffer 50m) • Punti di interesse (MIBACT e POI) at a maximum distance of 3km from reception centres and 1km from hotels	• MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • Corine Land Cover 2.4. Zone agricole eterogenee • Corine Land Cover 3.Territori boscati outside protected areas REM Marche: Aree protette: ZPS, SIC, EUAP, Natura 2000	• Punti di interesse (MIBACT e POI) at a maximum distance of 1km from hotels, but at least 3km from reception centres • Aree restanti	• OSM: Rete sentieristica (Buffer 50m) • Punti di interesse (MIBACT e POI): Locali storici (Buffer 1km) • Punti di interesse (MIBACT e POI) at a distance of more than 1km from hotels, but less than 3km from reception centres	• Corine Land Cover 1.1. Zone urbanizzate di tipo residenziale • ISTAT: Percorsi museali in Italia nel 2018 (Buffer 50m) • Punti di interesse (MIBACT e POI) at a distance of more than 1km from hotels and more than 3km from reception centres • Corine Land Cover 2.2. Colture permanenti • REM Marche: Aree protette: ZPS, SIC, EUAP, Natura 2000

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<table>
<tr><td rowspan="2">Rationale</td><td colspan="5">TRADE/INDUSTRY
This system welcomes proposals for multifunctional companies with a multi-sectoral approach, which implies the integration of different sectors such as industry, handicrafts, food and wine, and cultural, environmental and landscape values, enabling them to demonstrate a greater capacity to generate additional income. The structural shift towards knowledge-intensive services should be accelerated in order to attract qualified young people and increase productivity by strengthening the understanding of new markets. Policies supporting research and innovation activities, such as university-business partnerships or the creation/improvement of higher education schools, should be implemented, enhancing professional skills, training young people in traditional knowledge and bringing back jobs that have been outsourced. The digitisation of artisanal enterprises and the promotion of e-commerce are encouraged to create new marketing and communication strategies for products, integrating them with the territory. Participative projects within cooperatives can foster an increase in cultivated biodiversity and ensure the right rotations, considering the specific characteristics of each region. Exploiting Italy's competitive advantage in high-quality production, promoting the competitiveness of enterprises internationally by increasing the value of brands for commercial and tourism purposes (Made in Italy) and capitalising on industrial tourism are promising prospects. Enhancing the value of Made in Italy, with the aim of raising consumer awareness of the distinctive quality of the product through the narration of the historical roots of places.</td></tr>
<tr><td colspan="5">Suggested actions (projects or policies)
• Increasing productivity (university-business partnerships);
• Promoting multifunctional and multi-sectoral businesses;
• Sector Integration;
• Training of young people (Schools of Higher Education);
• Policies to support research and innovation;
• Enterprise digitisation and e-commerce;
• Exploiting the competitive advantage of Made in Italy.</td></tr>
<tr><td></td><td>Existing</td><td>Not appropriate</td><td>Capable</td><td>suitable</td><td>Feasible</td></tr>
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Descriptio n	• Industrial, commercial and infrastructure zones • Mining areas	• Areas at risk of landslides or flooding • Artificial green areas	• Area of commercial relevance: low concentration of commercial activities • Agricultural areas (arable land)	• Diffuse artificial areas	• Area of commercial relevance: high concentration of commercial activities • Artificial areas with continuous fabric
Data	• Corine Land Cover 2008	• MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • Corine Land Cover	• Open Street Map: Commercio	• Corine Land Cover 2008	• Open Street Map: Commercio • Corine Land Cover 2008
Operators	• Corine Land Cover 1.3.1. Aree estrattive • Corine Land Cover 1.2. Zone industriali, commerciali ed infrastrutturali	• MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • Corine Land Cover 1.4. Zone verdi artificiali non agricole	• OSM: Punti vendita (Kernel: pertinenza mediana) • Corine Land Cover 2.1. Seminativi	• Corine Land Cover 1.1.2. Zone residenziali a tessuto discontinuo e rado	• OSM: Punti vendita (Kernel: pertinenza alta) • Corine Land Cover 1.1.1. Zone residenziali a tessuto continuo

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Rationale

HOUSING

This system accommodates projects and policies aimed at the recovery of the existing building heritage and for the development of multifunctional diffuse hospitality (e.g. tourists, the elderly, students). It deals with aspects of post-earthquake reconstruction, improvement of the physical structure of buildings against earthquakes and their energy efficiency.

Suggested actions (projects or policies)

- Supporting the integration of minorities;
- Regeneration of real estate assets;
- Reconstruction of the built heritage;
- Improving the building structure against earthquakes;
- Energy efficiency;
- Identification of new building spaces;
- Provision of new areas for and new emergency facilities;
- Dispersed hospitality: rehabilitation of the built heritage to accommodate different targets (tourists, students, displaced persons);
- Creation of new spaces for gathering and socialising;
- Creation of citizen networks (students, psychological support, decision-makers);
- Evaluation and implementation of proximity centres for the provision of decentralised public services.

	Existing	Not appropriate	Capable	suitable	Feasible
classification	Is where the system is "existing" already and in a healthy state, meaning that it is feasible to remain a constraint in terms of information but not a total Constraint.	Is lowest priority for change "not appropriate" or not capable of supporting the system, meaning don't put it there, e.g., too wet or steep or unless you provide change to the basic area conditions e.g., fill in the ocean for new land, regrade the mountain, etc. (all very risky projects). This is also a constraint in terms of information.	Is low but higher priority "capable", meaning that you can place it here IF you also provide the technology and market to make it feasible, e.g., water and sewers, access roads for mechanical harvesting, etc., and the market comes	Is higher priority "suitable", meaning that the area is capable of supporting the project and it already has the appropriate technologies to support the activity taking place e.g., septic tank soil or sewers, access roads for mechanical harvesting, etc. BUT there may not yet be a market for the change.	Is the highest priority for change "feasible", meaning that it is suitable AND there is a demand or market to provide the new land use change, e.g., that someone wants to buy the product or new house (and at a profit) OR that the government wants to protect and improve an historical landscape.

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Description	• -	• Areas at environmental risk (landslides or flooding) • Incompatible uses: industrial areas, mining, construction sites, forests, wetlands, agricultural areas with valuable crops, protected natural areas.	• Areas with good quality construction	• Areas with median quality buildings	• Areas with poor quality construction
Data	• -	• MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • Corine Land Cover 2008 • REM Marche: Aree protette	• Quality of housing (Algebraic sum of the number of inhabited historical buildings and their state of maintenance, obtained through population percentages) Base: ISTAT	• Quality of housing (Algebraic sum of the number of inhabited historical buildings and their state of maintenance, obtained through population percentages) Base: ISTAT	• Quality of housing (Algebraic sum of the number of inhabited historical buildings and their state of maintenance, obtained through population percentages) Base: ISTAT

Operators	• -	• MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • Corine Land Cover 1.2. Zone industriali, commerciali ed infrastrutturali • Corine Land Cover 1.3. Zone estrattive, cantieri, discariche e terreni artefatti e abbandonati • Corine Land Cover 1.4. Zone verdi artificiali non agricole • Corine Land Cover 3. • Corine Land Cover 4. Zone umide • Corine Land Cover 3. Corpi idrici • Corine Land Cover 2.2. Colture permanenti • REM Marche: Aree protette: ZPS, SIC, EUAP, Natura 2000 •	• Quality of housing – high	Quality of housing – medium	Quality of housing - low

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<table>
<tr><td rowspan="2">Rationale</td><td colspan="5">SMART
This system accommodates proposals for multifunctional companies with a multi-sectoral approach, which implies the integration of different sectors such as industry, crafts, food and wine, and cultural, environmental and landscape values. It aims to increase the research and development potential of innovative start-ups supported through the identification of research HUBs where both the research and business worlds are located, so as to create the conditions for a cross-fertilisation that is best implemented in informal situations. It is essential to provide for the digital transition of inland areas, both physically through the implementation of mixed infrastructure (energy and ultra-wide bandwidth) throughout the territory, and immaterially by promoting the digitisation of administrative and cultural processes. The digitisation of public administration offers greater capacity and speed in obtaining data, improvements in management, access to information and transparency in processes; in the cultural sector, it facilitates access and dissemination for tourism purposes. Through access to ultra-wideband, public and private buildings can benefit from IoT activities, such as security control, energy-saving environmental, presence and lighting sensors, as well as new services and activities for the cultural sector, such as digital exhibitions and immersive activities. To this end, training for the digital world is essential, with the opening of new schools and vocational courses or the encouragement of existing ones. Such courses should be prioritised to bridge the digital divide, giving different age groups and citizens from peripheral locations the same rights and access as everyone else. The ad hoc training process must be able to create job opportunities for young people, curbing their migration and attracting non-EU migrants, who often occupy positions below their qualifications.</td></tr>
<tr><td colspan="5">Suggested actions (projects or policies)
Supporting the digital transition;
Implementation of mixed infrastructure (energy and ultra-wideband);
Forecasting IoT activities;
Redevelopment of peri-urban spaces;
Redevelopment of public spaces;
Enhancement of traditional and digital craftsmen;
Support for forms of technology and know-how transfer;
Creation of integrated management bodies at inter-municipal level;
Implementation of shared IT systems and standards for integrated data management;
Promoting training for the digital world.</td></tr>
<tr><td></td><td>Existing</td><td>Not appropriate</td><td>Capable</td><td>suitable</td><td>Feasible</td></tr>
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Descriptio n	• Higher education centres	• Areas subject to natural hazards • Leisure Areas • Incompatible uses: protected natural areas, mining areas and forested areas	•	• Artificial Surfaces	• Vocational schools, high schools and other training and research centres
Data	• Open Street Map: University	• MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • Open Street Map: Leisure • Copernicus Digital Elevation Model (DEM)	•	• Corine Land Cover 2008	• Open Street Map: College • Open Street Map: Scuole
Operators	• OSM: University	• MASE-Geoportale Nazionale: Alluvioni - Estensione dell'area allagabile (PGRA 2021) • MASE-Geoportale Nazionale: PAI Pericolosità Idrogeologica: aree di frana • OSM: Leisure • Usi imcompatibli: REM Marche: Aree protette: ZPS, SIC, EUAP, Natura 2000, Corine Land Cover 3. Territori boscati e ambienti semi-naturali e 5. Corpi Idrici • Áreas fora da área urbana e das áreas não apropriadas (em amarelo) com inclinação maior que 10%	• Area rimanente	• Corine Land Cover 1. Superfici artificiali	• Open Street Map: College • Open Street Map: Scuole

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ARPAM	Stato Ecologico dei Corpi Idrici	https://www.arpa.marche.it/fiumi-nuovo
Comune di Camerino	Perimetrazione "Zona Rossa" del 18/05/2023	https://www.comune.camerino.mc.it/avvisi-cms/sisma-ottobre-2016-perimetrazione-zona-rossa-del-18-05-2023/
GoodPA Open Data Regione Marche	Punti di Interesse Turistico	https://dati.regione.marche.it/sl/dataset/punti-di-interesse-turistico
Geoportale Nazionale per l'archeologia: MIBACT	Catalogo Generale dei Beni Culturali (ICCD)	https://gna.cultura.gov.it/mappa.html?sezione=catalogo
Geoportale Nazionale per l'archeologia	Dati GNA: Siti archeologici	https://gna.cultura.gov.it/mappa.html
ISTAT	Percorsi museali in Italia nel 2018	https://www.istat.it/statistica-sperimentale/i-percorsi-museali-in-italia-nel-2018/

Appendix C

Results of the first design proposals

Here we present all the proposals drawn up individually for each system. Some proposals were excluded during this phase, usually due to errors in preparation that were corrected and generated new proposals. The results of the proposals can be viewed interactively here[1]: https://www.geodesignhub.com/p/3a94920b5dc0ff78/design/

Green infrastructure

For green infrastructure, a total of 23 proposals were submitted, of which 9 were later excluded or modified. The remaining 14 are:

1. Ecological corridor north of Camerino, near Mecciano, between Edilasfalti & C. S.R.L. and the IP petrol station, cutting through the Provincial Road 256 Muccese and Pedemontana. 0.72 ha and 70k EUR, public works.
2. Ecological corridor south of Camerino, cutting through the Provincial Road 256 Muccese near Pedemontana. 0.19 ha and 70k EUR, public works.
3. Natura 2000 integration network, on the southern outskirts of Camerino, between Strada Provinciale 132 and Via Italia Baudana Vaccolini. 6.68 ha, public+private.
4. Scenic viewpoint towards the valley, in the area of the demolition of the former Ugo Betti school in the historic center, near the Unicam Rectorate. 0.02 ha, 200k EUR, public.
5. Green infrastructure, in the northeastern outskirts of Camerino. 107.59 ha, public+private.
6. Green area (sparse), in the historic center of Camerino, in the area of the demolished courthouse. 0.04 ha, 400k EUR, public.
7. Green space, in Piazza Giuseppe Mazzini. 0.03 ha, 100k EUR, public.
8. Urban reforestation areas, three green areas surrounding the city. 470.82 ha, public+private.
9. Green infrastructure, in the green area on the western outskirts of Camerino. 29.74 ha.
10. City boundaries / buffer zones, a green belt surrounding the entire city. 108.93 ha, public+private.
11. Green Way for Green Park, pathways connecting protected areas. 85.34 km, public.
12. Transversal green corridors in the Verdicchio Valley, green corridors connecting protected areas. 5450.07 ha, 5.45M EUR, public+private.
13. Ecological gateways for biopermeability, two gates, one north and one south of the Gola di Sant’Eustachio, Monte d’Aria, and Monte Letegge complex. 1.64 km, 10k EUR, public+private.
14. Reforestation interventions in degraded areas, a unique green infrastructure policy covering the entire eastern region of the Crater, which lacks protected areas. 1M EUR, other.

[1] You may need to create a free account to access it..

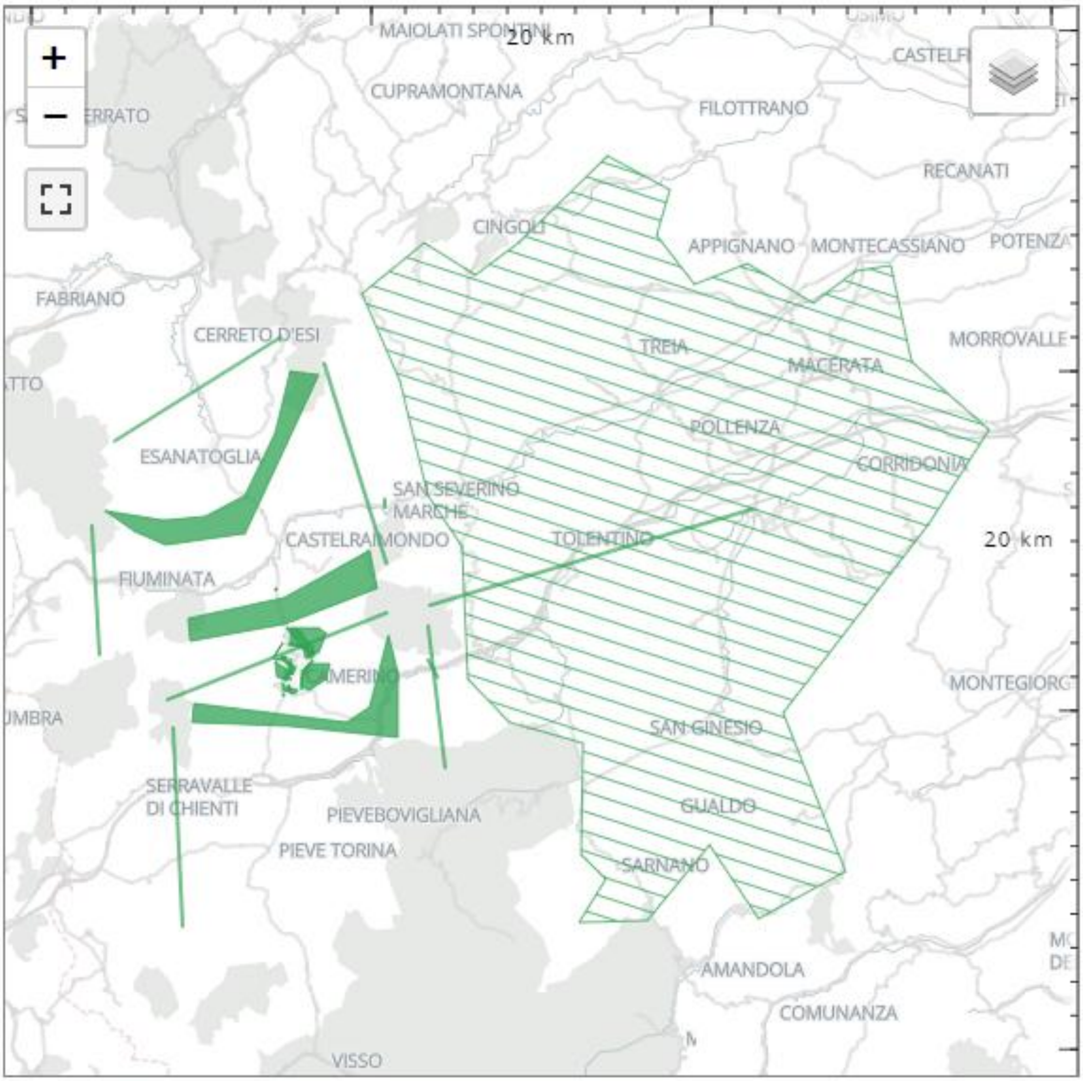
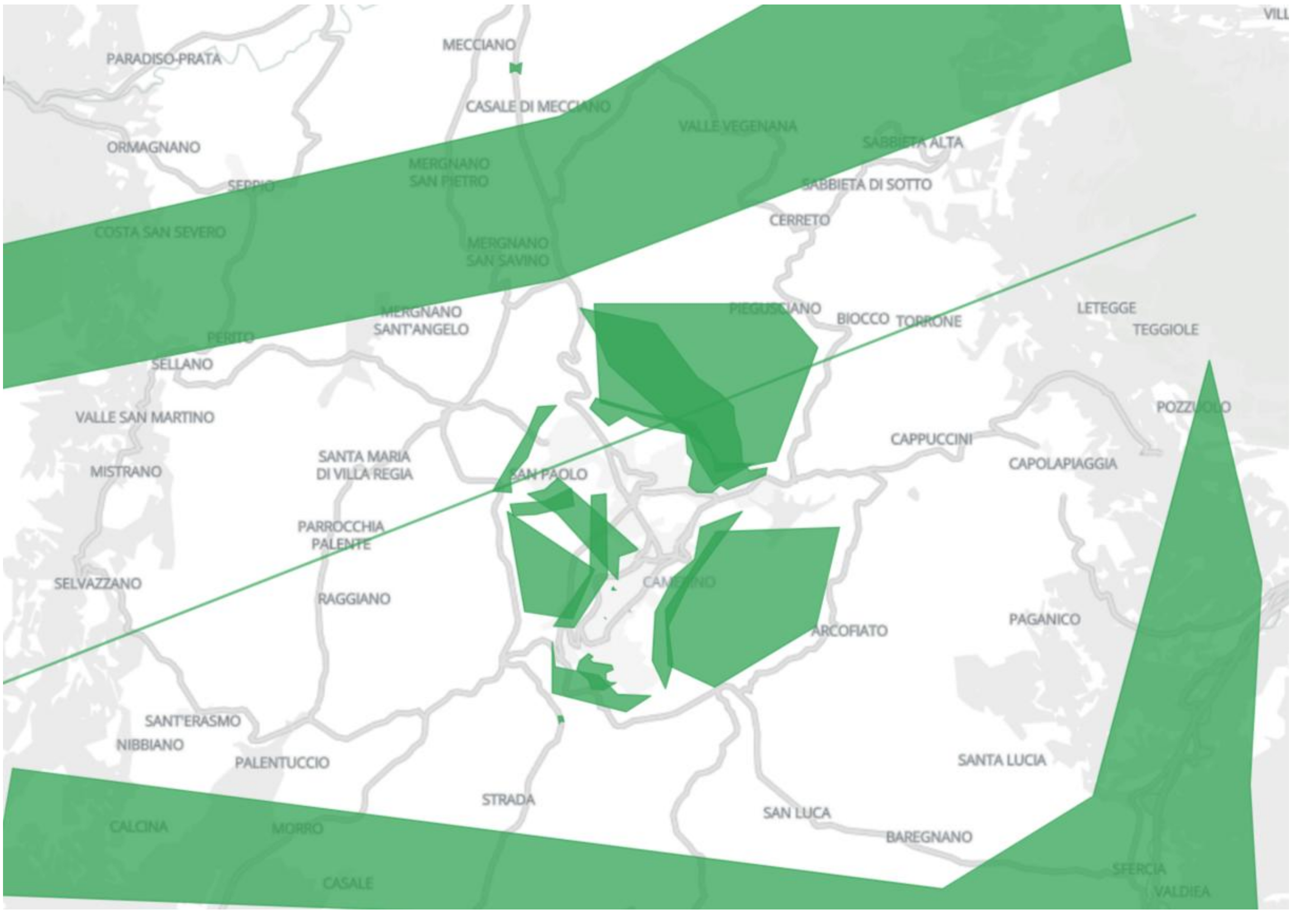


Figure 1: Summary map of all the Green Infrastructure proposals. Source: Author



Some proposals overlap, especially near the city.

Infraestutura azul

Blue Infrastructure received a total of 11 proposals, 5 of which were removed due to errors or because they had been redesigned.

1. Phytoremediation plant, in the northern outskirts of the city, near the Montagnaro Student Housing of the University of Camerino. 7.21 ha, 700k EUR, public.
2. Water storage basin (irrigation), in the agricultural area southwest of the city of Camerino. 10.6 ha, 212k EUR, public.
3. New thermal area, on Monte di Mistrano, north of the Fonte del Gallo Cave. 23.77 ha, 500k EUR, public.
4. Water storage basin (irrigation), near the Potenza River, at the border between the municipalities of Tolentino and Passo di Treia. 18.43 ha, 368.6k EUR, public.
5. Water route, following the Fosso di Selvazzano, between the town of Selvazzano and Monte Torroncello. 2.54 km, public.
6. River parks, following the course of the Potenza and Chienti rivers from the outskirts of Camerino to the boundary of the Crater area in the Marche region. 84.17 km, 10k EUR, public+private.

Figure 3: Summary map of all the Blue Infrastructure proposals.

Agriculture

The agricultural system had a total of 14 proposals, one of which was deleted.

1. Network of places to share local products, in the area adjacent to Piazza Dario Conti. 0.78 ha, 97.5k EUR, public+private.
2. Local production + educational workshops, in an area south of Quartiere San Paolo. 16.83 ha, 10k EUR, private.
3. Market for Km0 products, between SAE San Paolo and ITCG Giovanni Antinori. 0.76 ha, 95k EUR, public+private.
4. Community gardens, in the green area north of the Unicam Campus and Agriturismo La Finestrella, on the northern outskirts of Camerino. 3.41 ha, 10k EUR, public.
5. Agri-tourism, covering the entire area between the city of Camerino and the protected area to the east. 3219.74 ha, 200k EUR, private.
6. Agriculture and hydrogeological instability, a policy covering the entire area between the city of Camerino and the protected area to the east, and from the Potenza River to the Chienti River.
7. Trees for life, in the wooded areas of Cingoli between Pian dei Conti, Monte Nero, Cristo delle Marche, Internone, and Macchia delle Tassinete. 4842.68 ha, 2M EUR, public+private.
8. Pig farming, in two agricultural areas north and south of Muccia. 643.55 ha, 965.32k EUR, public+private.
9. Cultivation for livestock farming, in an agricultural area at the foot of the Colleluce and Schiena mountains, covering the towns of Serrapetrona and Colleluce towards Tolentino. 1754.84 ha, 1.75M EUR, public+private.
10. Network of places to share local products Sottocorte V, reserving part of the rooms in the Sottocorte Village, in the northern area of Camerino, built after the earthquake. 0.07 ha, 8.75k EUR, public+private.
11. Local production and educational workshops, on the southern outskirts of Torre del Parco, near the Pasta di Camerino factory and Synbiotec (a Unicam spin-off). 0.99 ha, 10k EUR, private.
12. Agricultural park, in the southeastern area of Camerino up to Colle Rana, including Monte Capolapiaggia and Monte Paganico. 3219.74 ha, 200k EUR, private (policy).

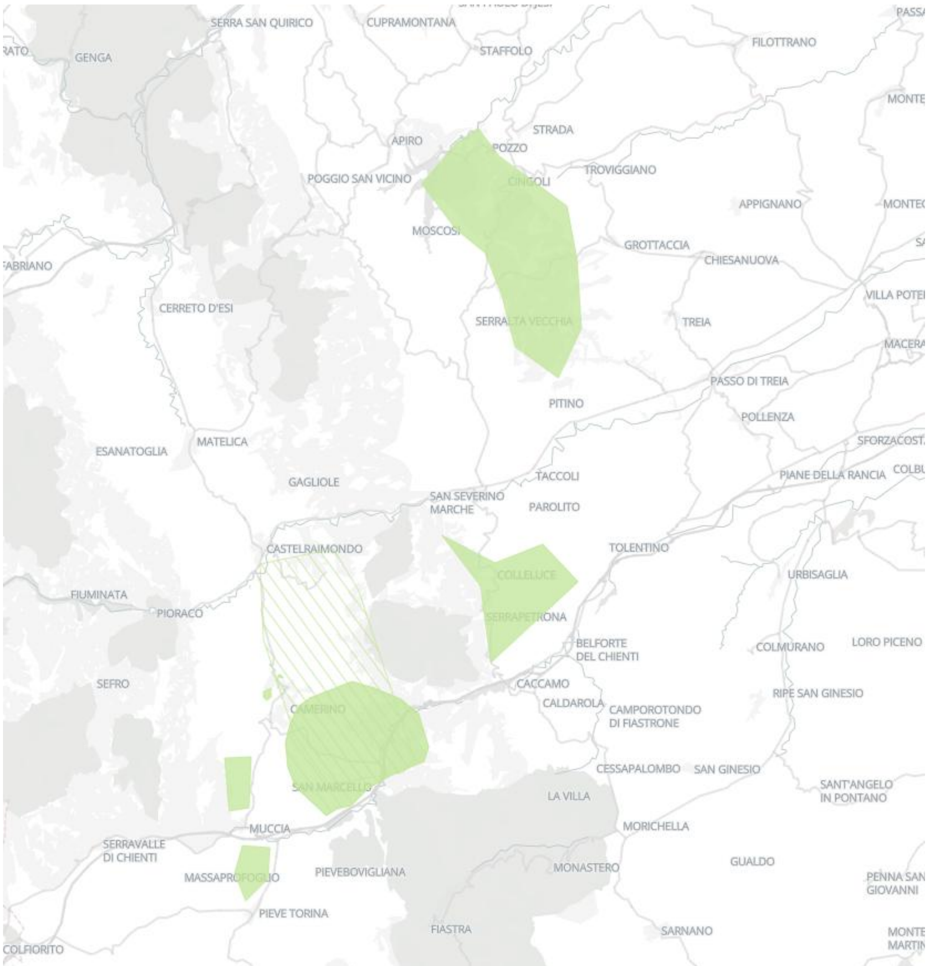


Figure 4: Summary map of all the proposals for the agricultural system.

Transportation

The transport system generated 17 proposals.

1. Urban cable car, connecting the historic center of Camerino to the Centro Universitario Sportivo Sergio Sabbieti Le Calvie, passing through Quartiere San Paolo. 2.34 km, 20M EUR, public.
2. New park-and-ride facility, at the intersection of Strada Provinciale 94 and the road leading from San Paolo to Villa Fornari. 1.66 ha, 207.5k EUR, public.
3. Unicam car-sharing station, inside the Unicam Campus, with an entrance on Via Andrea d'Accorso. 0.07 ha, 100k EUR, public.
4. Mechanized funicular route, connecting the center of Camerino (Porta Malatesta) to Strada Provinciale 17. 0.69 km, public.
5. Construction of a cycling and pedestrian path from the student housing to the CUS, linking the entire northern part of Camerino, from Foresteria EDIS to the Unicam Campus and finally to the CUS. 3.15 km, public.
6. Improvement of pedestrian mobility (sidewalks) on Via Madonna delle Carceri, from Chiesa di Santa Caterina to the new Polo Scolastico Provinciale di Camerino. 0.77 km, public.
7. Network of bike/hike hubs, in a green area on the eastern outskirts of the historic center, adjacent to Basilica di San Venanzio. 0.46 ha, 57.5k EUR, public+private.
8. Electric scooter rental area, in the northern part of Piazza della Vittoria. 0.02 ha, 2k EUR, private.
9. Electric bike/scooter charging stations, near Contram in Camerino. 0.1 ha, 12.5k EUR, public.
10. Surface funicular, connecting the historic center (Civic and Diocesan Museums) to the CUS, passing through San Paolo. 22.96 ha, 2.87M EUR, public+private.
11. Cycling and pedestrian route, starting from the CUS along Strada Provinciale 256, circling the historic center via Strada Provinciale 256 and Viale Giacomo Leopardi, and covering the northern area via Via Le Mosse and Andrea D'Accorso. 9.82 km, 3M EUR, private.
12. Cycling and pedestrian route connecting green areas, a new path through rural areas on the outskirts, circling the city of Camerino. 8.97 km, public.
13. Bus connection Camerino-Foligno, linking Camerino to Foligno and Foligno to Monte Puranno. 48.36 km, public.
14. Bus connection to Ascoli Piceno, passing through Amandola. 58.03 km, public+private.
15. Bus connection to Ancona. 62.99 km, public+private.
16. Network of bike/hike hubs, at the intersection of Strada Provinciale 94 and the road leading from San Paolo to Villa Fornari and Pedemontana, near the CUS. 0.99 ha, 123.75k EUR, public+private.
17. Electric bike/scooter charging stations, at the intersection of Strada Provinciale 94 and the road leading from San Paolo to Villa Fornari and Pedemontana, near the CUS. 0.17 ha, 21.25k EUR, public.

Figure 5: Summary map of all the proposals for the transport system.

Figure 6: Zoom of the transportation system near the city of Camerino

Trade and Industry

There were 11 proposals for this system, with one proposal canceled.

1. Hub for selling Km0 products, at the northern edge of the city, in the area built after the 2016 earthquake, within the Sottocorte Village shopping center. 0.13 ha, 16.25k EUR, public.
2. Completion of the industrial hub, on the southern outskirts of Torre del Parco, near the Pasta di Camerino factory and Synbiotec (a Unicam spin-off). 2.62 ha, 327.5k EUR, public.
3. Business center, in front of Chiesa Madonna delle Carceri in Camerino. 1.07 ha, 4M EUR, private.
4. CCB - Borgo Commercial Center, occupying a large area in the historic center of Camerino. 4.79 ha, 200k EUR, public+private.
5. Network of places to produce/sell local products, in the area of the former prison of Camerino. 0.19 ha, 23.75k EUR, public+private.
6. Country spa, within the Villa Fornari estate. 0.12 ha, 70k EUR, private.
7. Scientific park for start-ups, south of SAE San Paolo. 3 ha, 5M EUR, private.
8. Local products distribution center for the Crater Area, in an area near Strada Carrareccia, in the Peschiera region. 8.75 ha, 50k EUR, public+private.
9. Widespread commercial center, in the central area of the historic center. 4.79 ha, 200k EUR, public+private.
10. Place for start-ups in existing buildings, in the area of Palazzo Piazza Alta. 0.37 ha, 5M EUR, private.

Figure 7: Summary map of all the proposals for the Trade and Industry system.

Energy

There were 10 proposals, with 3 errors.

1. Schools and energy, in the area of the Polo Scolastico Provinciale di Camerino. 0.66 ha, 500k EUR, private.
2. Parking and energy, in the area of the Contram Mechanized Parking. 0.56 ha, 1M EUR, private.
3. Incentives for photovoltaic installations on industrial hub rooftops, in the Torre del Parco area. 27.85 ha, 3.48M EUR, public.
4. Camerino electric substation, in the rural outskirts of Camerino (east), near Via Scalette. 0.97 ha, 4.85k EUR, private.
5. Geothermal plant, at the northern edge of Sarnano. 3.24 ha, 405k EUR, public+private.
6. Biomass facility, in an area with access to Strada Statale 77, between Monte Faeto and Monte Prefoglio, centrally positioned within the protected area. 13.76 ha, 1.72M EUR, public+private.
7. Camerino hydroelectric plant, on the Chienti River, between Valdiea and Sfercia, near the Unicam power station. 2.73 ha, 13.65k EUR, private.

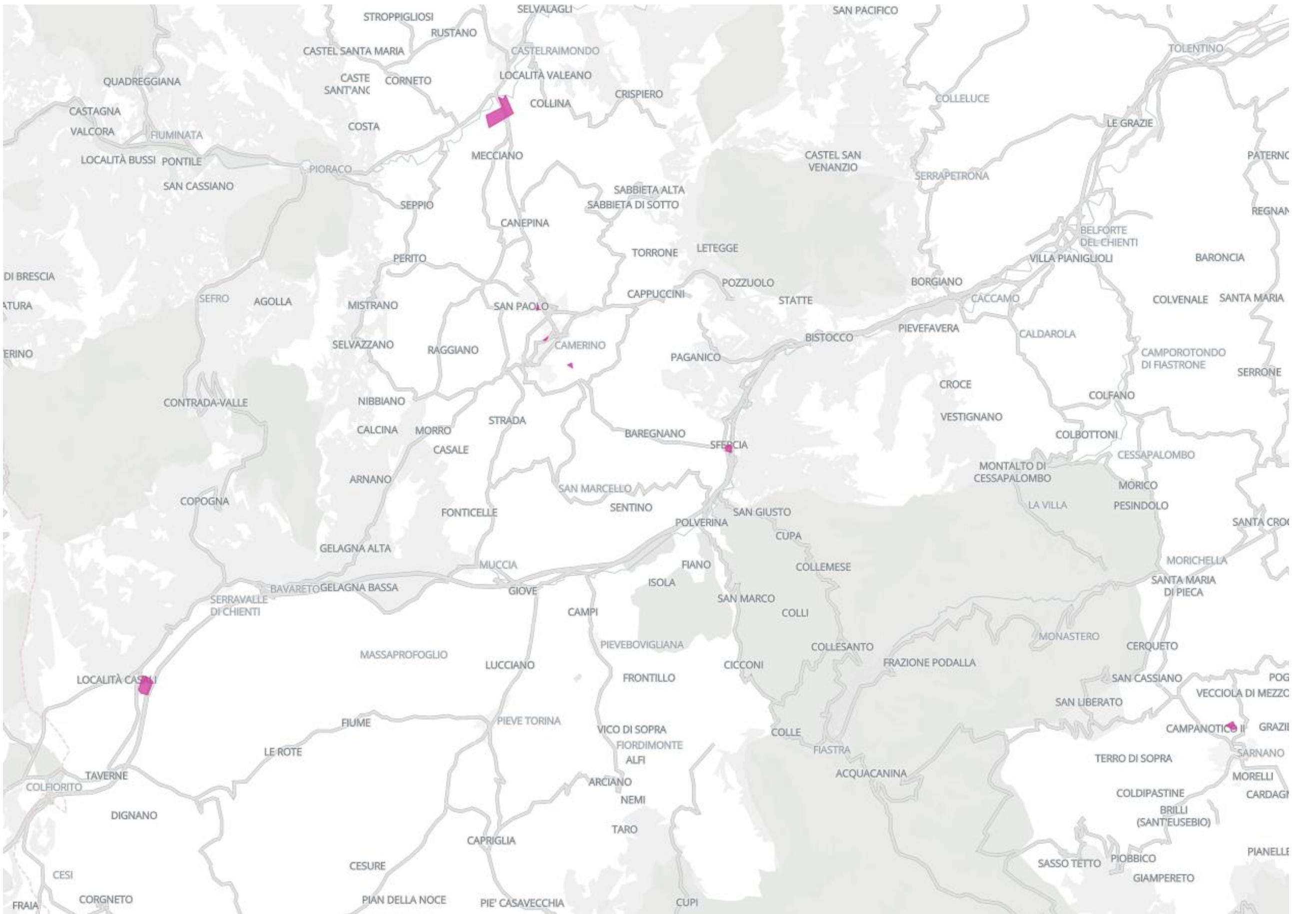


Figure 8: Summary map of all the proposals for the energy system.

Housing

There were 13 proposals, 4 of which were canceled.

1. RSA (former hospital), in the historic center of Camerino. 0.3 ha, 100k EUR, public+private.
2. Adolescents' house, in the area between SAE San Paolo and the Polo Scolastico Provinciale di Camerino. 0.3 ha, 37.5k EUR, public+private.
3. New residences - controlled rent, in the open area between Monastero del Col di Bove and the Carabinieri Forest Station in Camerino. 2.06 ha, 200k EUR, public.
4. Integrated residential housing (for elderly, foreigners, disabled), a policy for the entire red zone area of the historic center of Camerino. 20M EUR, other.
5. Building densification interventions in the existing urban fabric, in the northeastern area of Tolentino. 6.51 ha, 50k EUR, public.
6. SAE 2.0 - Social Housing, transformation of SAE 2.0 into social housing. 6.17 ha, 8.5M EUR, public.
7. Student recreation room, inside the Unicam Student Center in Camerino. 0.13 ha, 16.25k EUR, public.
8. Controlled rent housing, in SAE Vallicelle (northeastern edge) in Camerino. 0.6 ha, 75k EUR, public.
9. Densification near infrastructure, in the northeastern area of Tolentino. 3.46 ha, 50k EUR, public.

Figure 9: Summary map of all the proposals for the residential system.

Tourism

There were 13 proposals, 1 of which were canceled.

1. Network of public spaces for activities, in the parking area on Via Varino Favorino in the historic center of Camerino. 0.16 ha, 120k EUR, public+private.
2. Student tourism, inside the Unicam Student Center in Camerino. 0.1 ha, 12.5k EUR, public.
3. Network of public places for the local community, in a residential area bordering the Unicam Campus in Camerino. 0.22 ha, 27.5k EUR, public+private.
4. Camper parking area, in a site demolished by the 2016 earthquake at Collegio D'Avack - Università degli Studi di Camerino. 0.21 ha, 26.25k EUR, private.
5. Student tourism, four locations: Castelsantangelo sul Nera, Bolognola-Pintura, Castelraimondo, and Matélica. 14.36 ha, 1.8M EUR, public.
6. SAE 2.0, in the northernmost SAE area of Camerino. 0.73 ha, 700k EUR, public+private.
7. Scientific tourism, in the area of Collegio Universitario B. Bongiovanni. 0.09 ha, 11.25k EUR, public.
8. Scientific tourism, at the Unicam Campus in Camerino. 1.73 ha, 216.25k EUR, public.
9. Improvement and development of the Botanical Garden, in Camerino. 0.35 ha, 21k EUR, public.
10. Botanical garden - rare species, in the northwestern outskirts of Castelraimondo. 2.74 ha, 27.4k EUR, private.
11. Botanical garden - rare species, in the area south of the Abbadia di Fiastra Integral Reserve. 53 ha, 530k EUR, private.
12. SAE 2.0 for tourism, in the northernmost SAE area of Camerino (policy). 0.73 ha, 700k EUR, public+private.

Figure 10: Summary map of all the proposals for the tourism system.

Culture

There were 20 proposals. 3 of which were canceled.

1. Multipurpose cinema-theater, at the eastern edge of Camerino. 0.39 ha, 48.75k EUR, public.
2. Geological-seismic museum, in the Belvedere di Via Seneca area in Camerino. 0.18 ha, 100k EUR, public.
3. Open-air cinema, in the Belvedere di Via Seneca area in Camerino. 0.28 ha, 60k EUR, public+private.
4. Bike repair workshop, in the easternmost SAE area of Vallicelle. 0.04 ha, 5k EUR, private.
5. Associations' center, in the open area between CHIP - Chemistry Interdisciplinary Project - Unicam Research Center and the Urban Cemetery. 0.92 ha, 1.38M EUR, public+private.
6. Micro-Smart Hub - SAE Redevelopment, in the area of the Unicam Montagnaro Student Housing. 8.5 ha, 1.06M EUR, public.
7. Art Restoration Center, in the Rectorate building of Unicam in the historic center of Camerino. 0.07 ha, 17.5k EUR, public.
8. Restoration and redevelopment of Palazzo delle Esposte, in the historic center of Camerino. 0.23 ha, 28.75k EUR, public.
9. STEAM Technology Park, in Piazza Giuseppe Mazzini, Camerino. 0.02 ha, 2.5k EUR, public.
10. Discussion spaces, inside the Unicam Campus in Camerino. 0.67 ha, 83.75k EUR, public+private.
11. Shared gardens for students and residents, in the open area north of the Unicam Student Center. 4.16 ha, 520k EUR, public+private.
12. New contemporary architecture in the Old Town, four locations in the historic center of Camerino. 0.49 ha, 61.25k EUR, public+private.
13. Smart incubator, in the SAE area of Vallicelle. 0.49 ha, 61.25k EUR, private.
14. Religious and cultural route, connecting the churches and museums of Camerino. 4.45 km, 50k EUR, public.
15. Castle tour, a route through the castles in the municipality of Camerino. 31.2 km, 50k EUR, public.
16. Hilly lakes, an area between Cingoli, Macerata, Corridonia, and San Severino, with the western boundary defined by natural areas (policy). 3M EUR, other.
17. Micro-Smart Hub - SAE Redevelopment, in the northwestern SAE area of Camerino. 1.81 ha, 226.25k EUR, public.

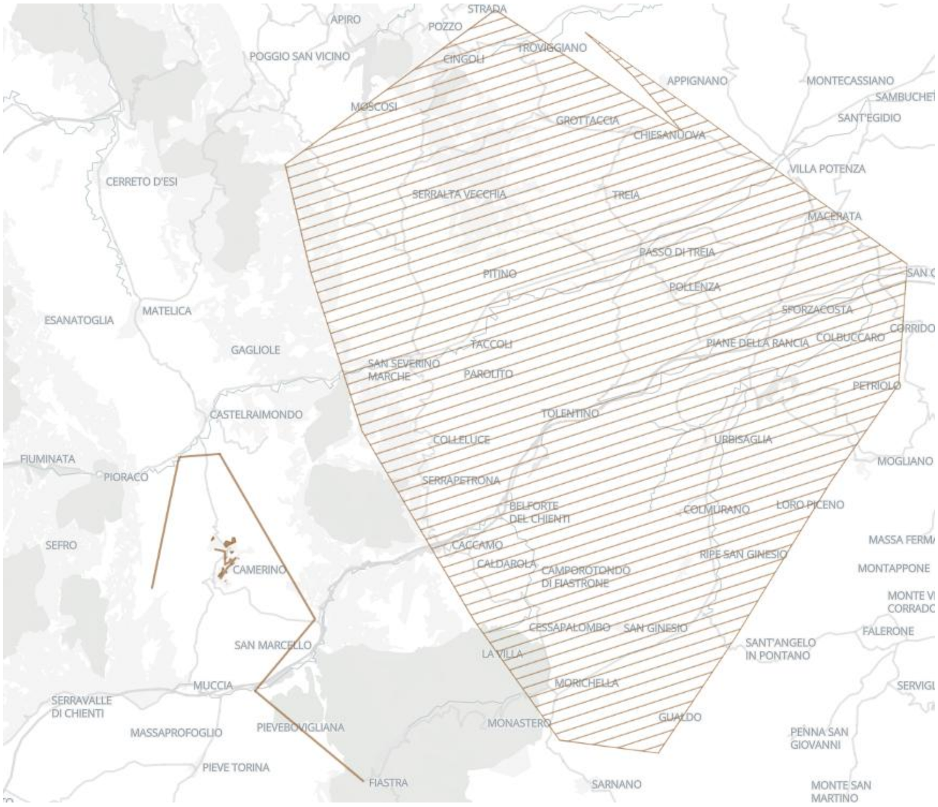


Figure 11: Summary map of all the proposals for the cultural assets system.

Smart

There were 11 proposals.

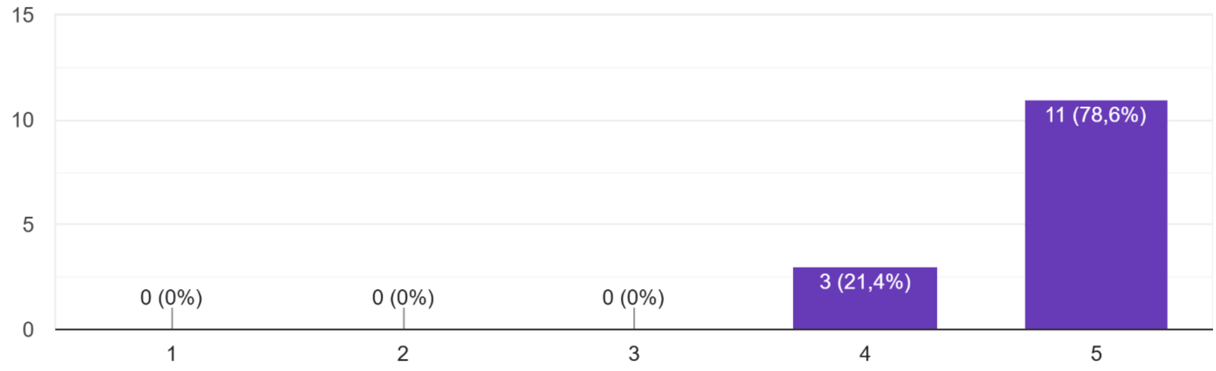
1. Digital eno-gastronomic and cultural route, along Via Camillo Lili and Corso Vittorio Emanuele in the historic center of Camerino. 0.56 km, 30k EUR, public+private.
2. San Domenico Virtual Museum, in the historic center of Camerino. 0.34 ha, 68k EUR, public.
3. Network of information hubs, in Piazza Cavour in the historic center of Camerino. 0.16 ha, 20k EUR, public+private.
4. Smart working hub, in the area of the demolished courthouse in Camerino. 0.1 ha, 80k EUR, private.
5. Tactical urbanism, in the parking area between Via Costanza Varano and Via Varino Favorino. 0.14 ha, 17.5k EUR, unknown.
6. Reactivation of the municipal theater and open-air theater, in the historic center of Camerino. 0.09 ha, 11.25k EUR, unknown.
7. Reactivation of the cinema, in Piazza Giuseppe Garibaldi in the historic center of Camerino. 0.04 ha, 200k EUR, public.
8. Network of places for yoga and meditation, in the northeastern part of the historic center of Camerino. 1.5 ha, 187.5k EUR, public+private.
9. Bike repair workshop, in the SAE area in Vallicelle. 0.03 ha, 200k EUR, private.
10. Technopole, in the area of Fiera di Villa Potenza. 3.41 ha, 100k EUR, private.
11. Enhanced smart pharmacy, at the Central Pharmacy of Camerino. 0.09 ha, 3M EUR, public+private.

Figure 12: Summary map of all the proposals for the SMART system.

Appendix D - Participatory process evaluation questionnaire

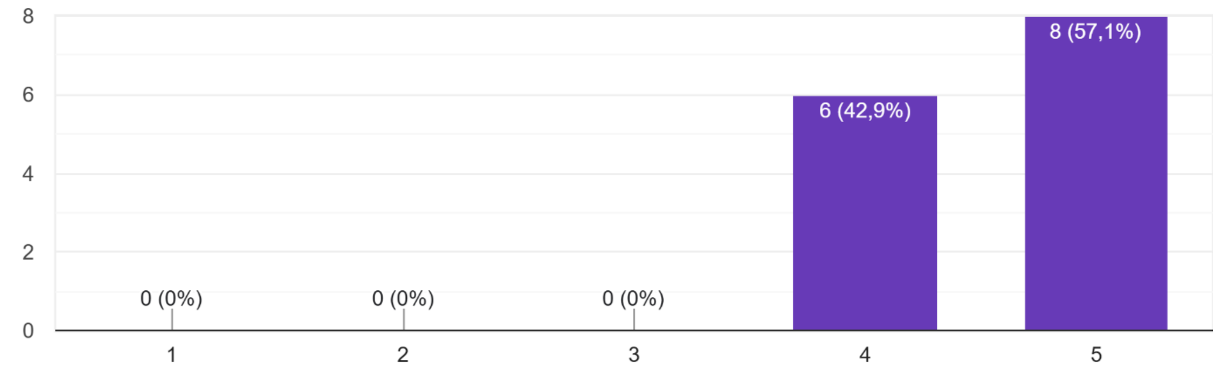
Sono soddisfatta/o di aver partecipato al workshop

14 risposte

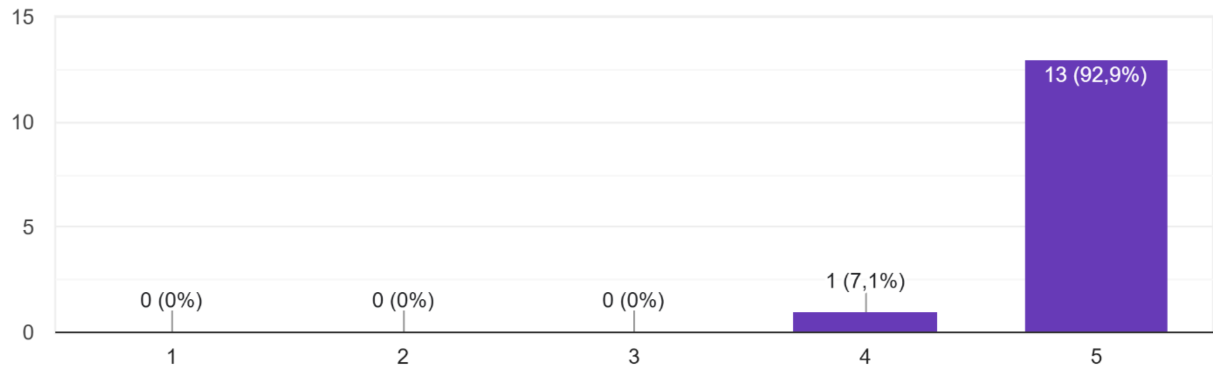


Gli obiettivi del workshop verso una maggiore resilienza del territorio sono stati raggiunti?

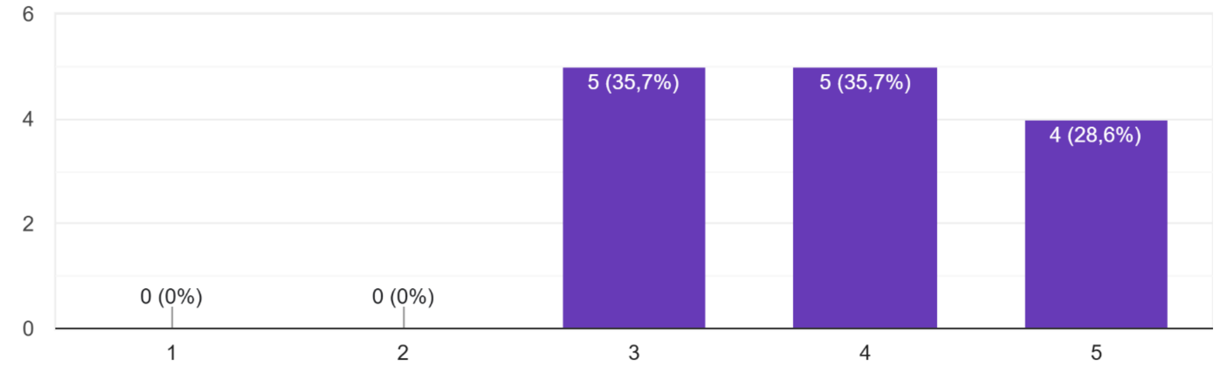
14 risposte



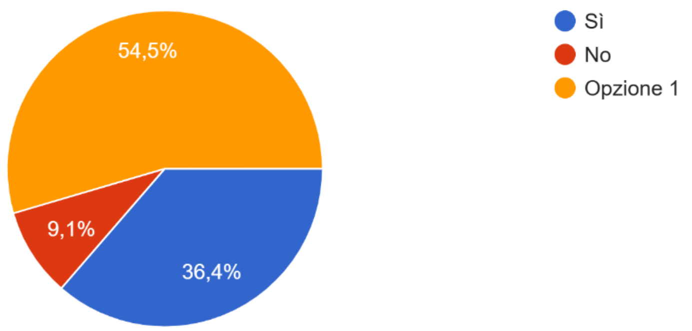
Secondo te il Geodesign aiuta a rendere più evidenti i punti importanti per accrescere la resilienza territoriale e delle comunità?
14 risposte



Hai avuto il tempo necessario nelle varie fasi del workshop per spiegare il tuo progetto?
14 risposte

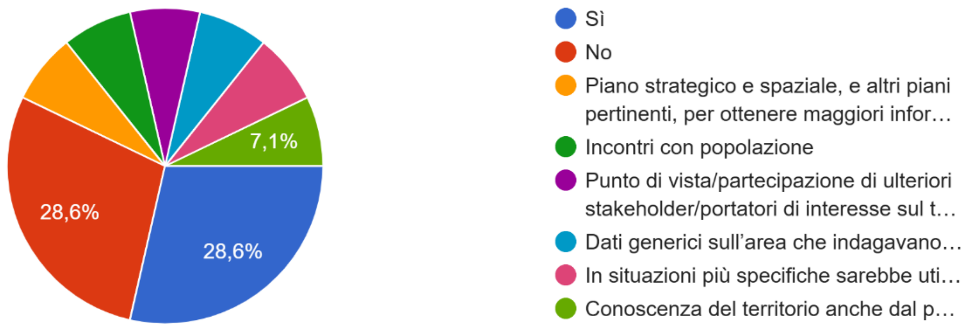


Ritieni che sarebbe stato necessario un sopralluogo a più ampio raggio?
11 risposte



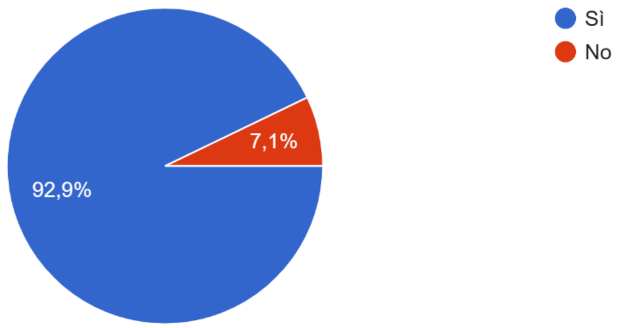
Ritieni che sarebbe stato utile disporre di altri tipi di informazioni? (se si indica quali in altro)

14 risposte



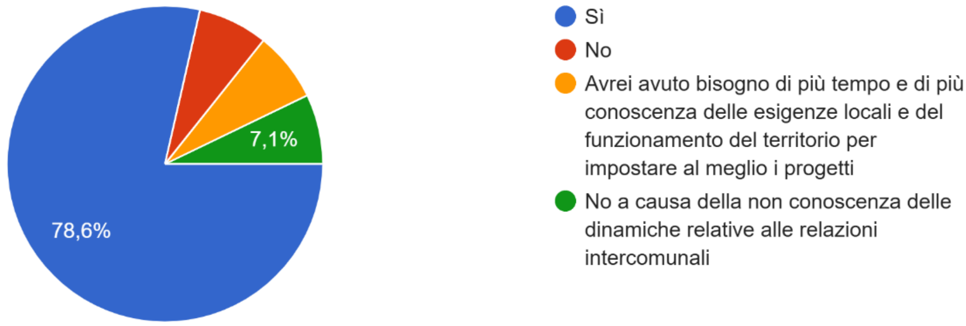
Nella piattaforma, hai avuto lo spazio necessario per spiegare il tuo progetto?

14 risposte



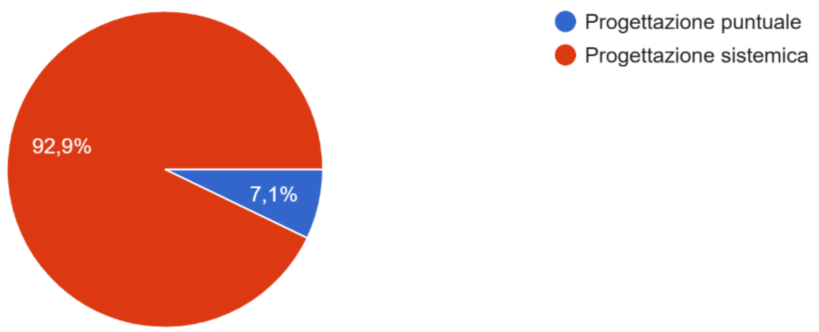
Nella formulazione dei progetti hai preso in considerazione le relazioni della città con il territorio e i centri circostanti?

14 risposte



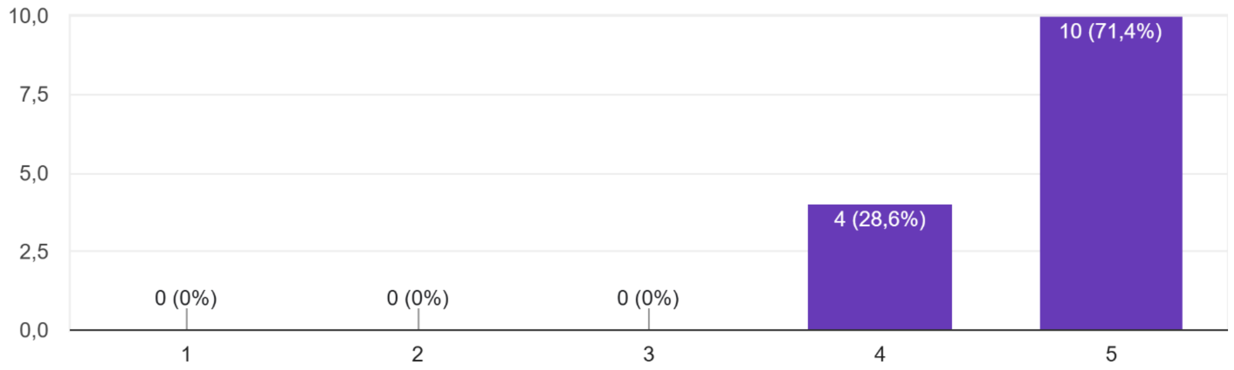
Per una maggiore resilienza delle aree interne ritiene più utile una progettazione puntuale (città e centri storici) o una progettazione sistemica/territoriale?

14 risposte



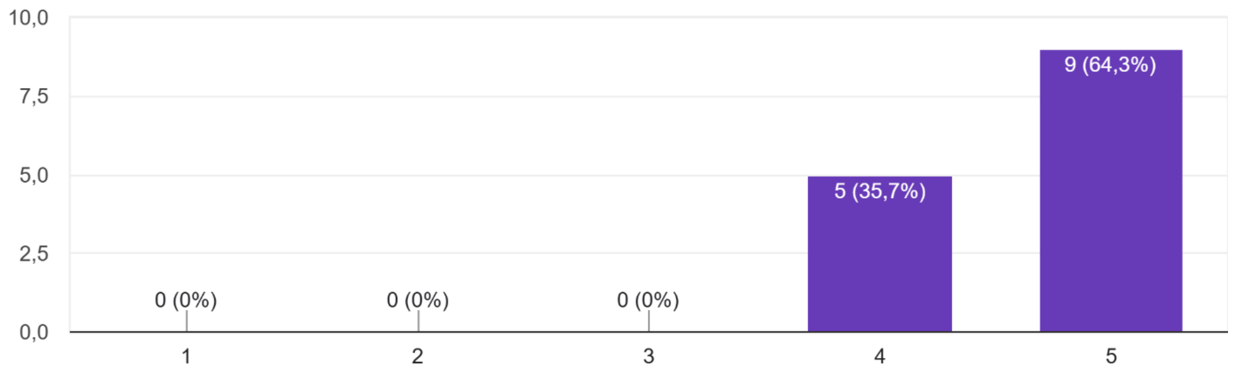
Gli strumenti utilizzati hanno consentito di raggiungere obiettivi e risultati più in fretta che con metodi abituali?

14 risposte



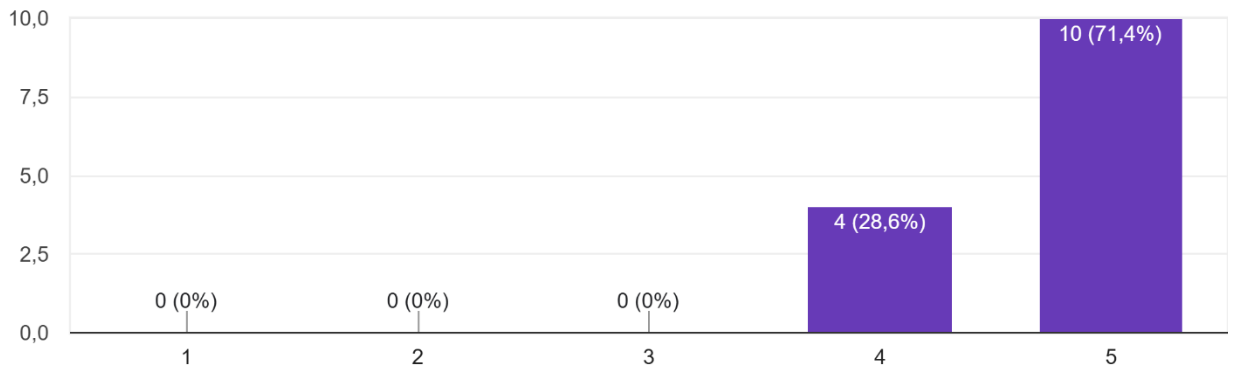
La sintesi progettuale finale tiene conto del tuo contributo?

14 risposte



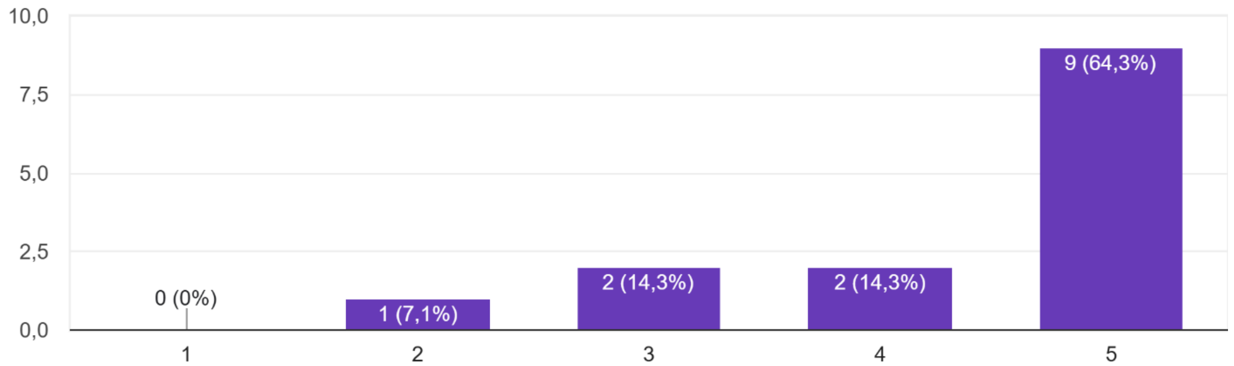
E' soddisfatta/o della sintesi progettuale finale in termini generali?

14 risposte



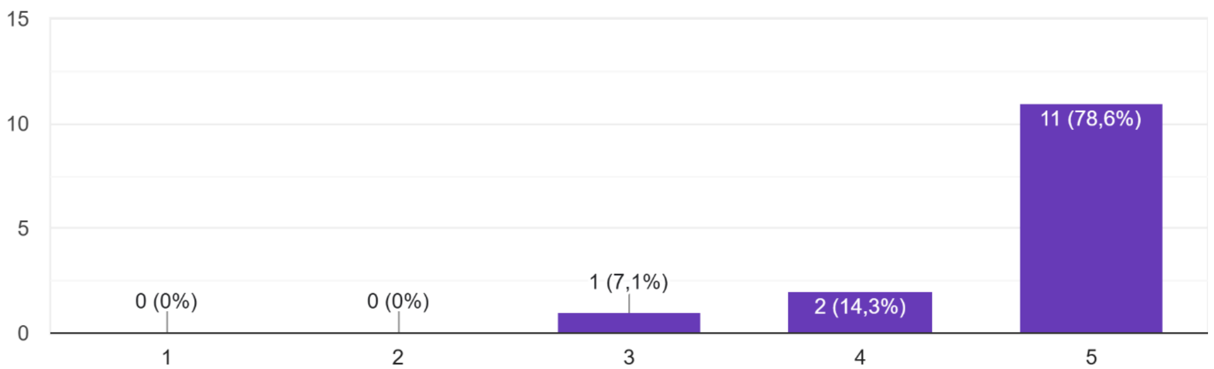
La sua conoscenza dell'area di studio è migliorata grazie alla partecipazione al workshop?

14 risposte

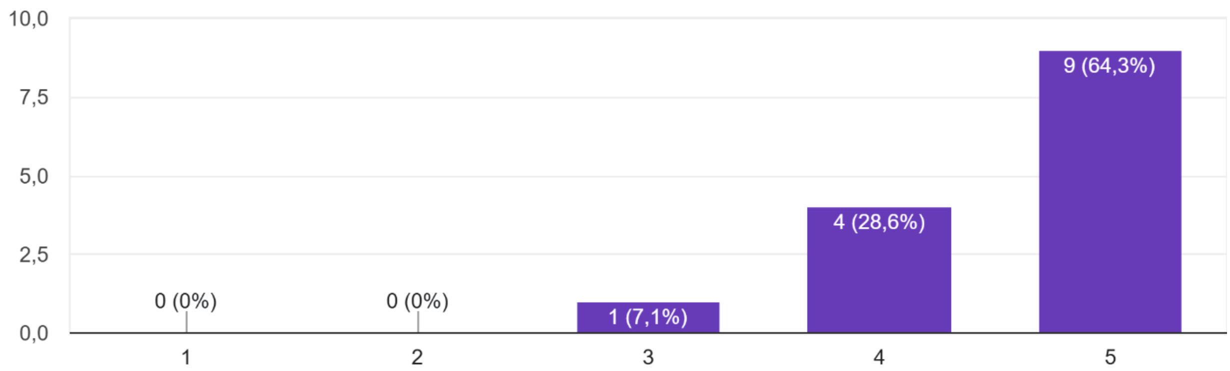


Il workshop ha facilitato la collaborazione con gli altri partecipanti?

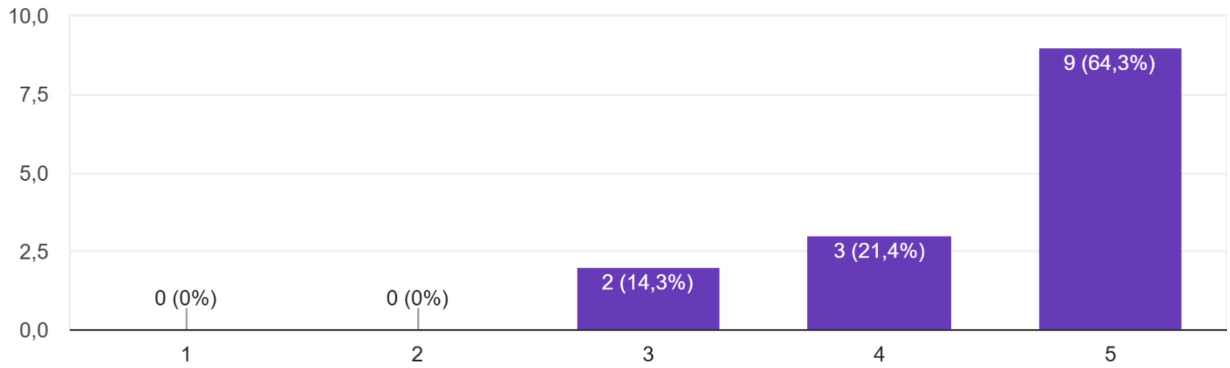
14 risposte



Senza il workshop di geodesign raggiungere gli stessi risultati avrebbe richiesto più tempo?
14 risposte

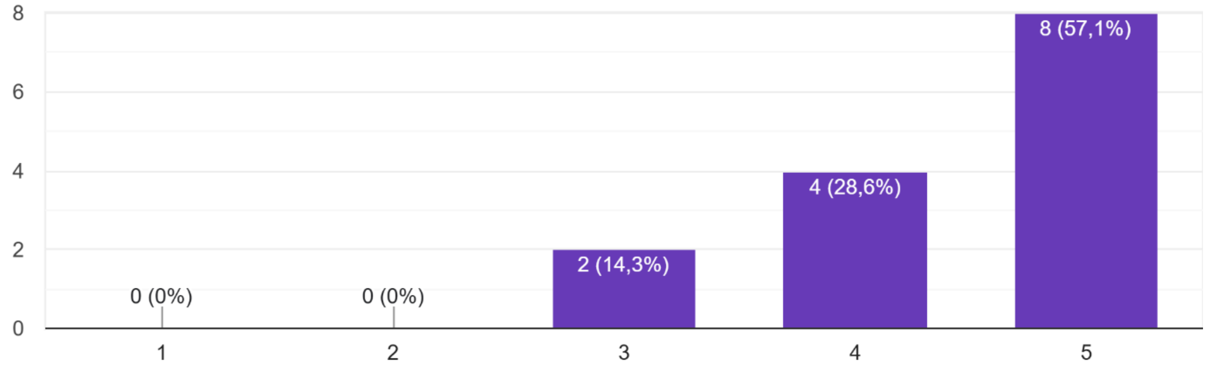


E' stato facile imparare ad utilizzare la piattaforma Geodesignhub?
14 risposte



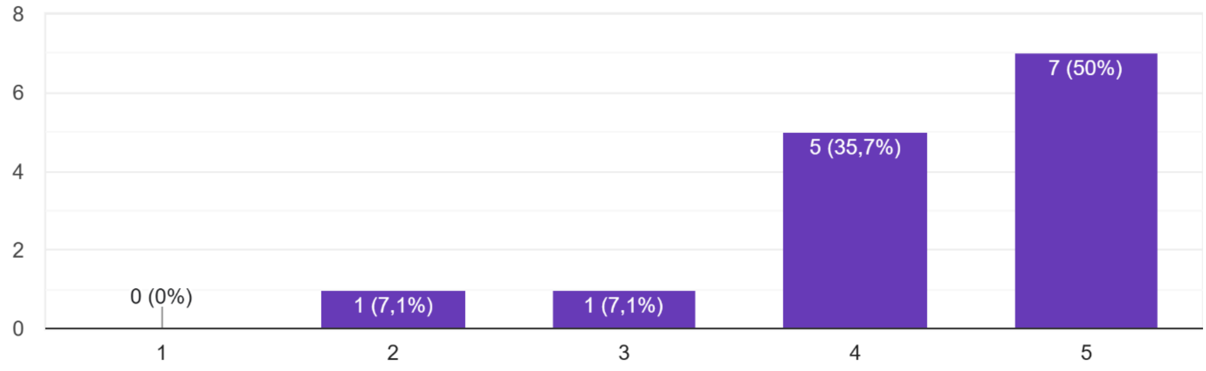
Le mappe di valutazione (rosso, giallo, verde) sono state un utile supporto al suo lavoro nel workshop?

14 risposte



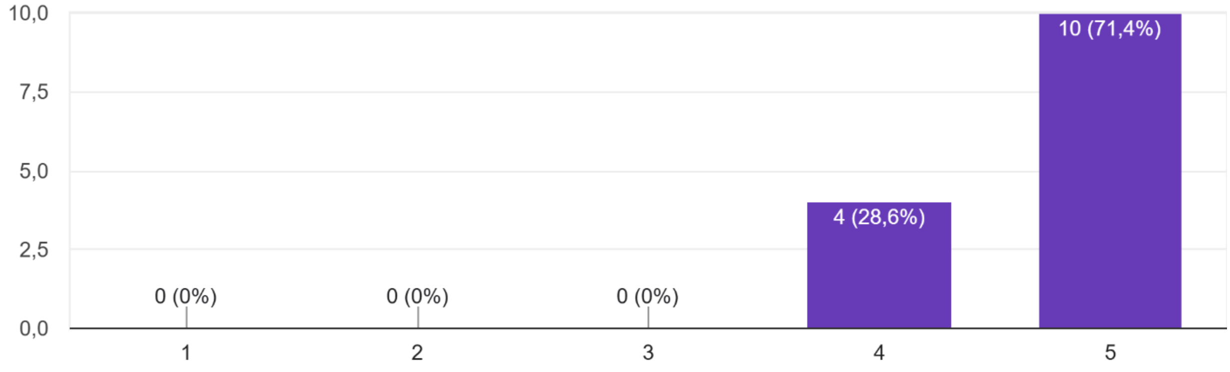
Ha tenuto conto delle mappe di valutazione per disegnare i diagrammi?

14 risposte



Crede che l'approccio del workshop di geodesign sia un utile strumento di supporto alla co-progettazione/co-pianificazione?

14 risposte



Commenti e suggerimenti (facoltativo)

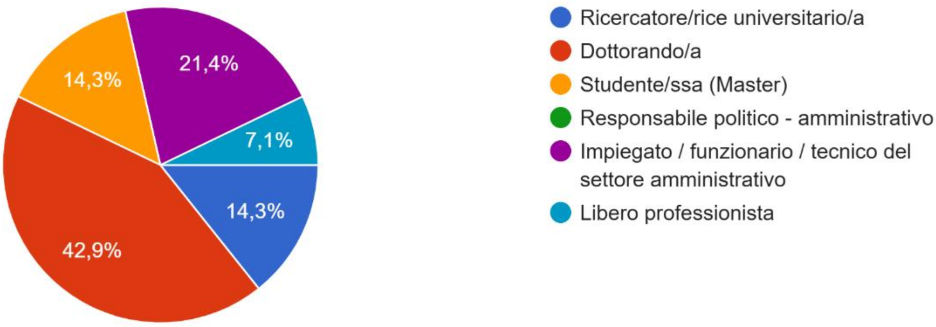
2 risposte

Sono molto contenta di aver partecipato al Geodesign Workshop: è una vera dimostrazione di resilienza sociale all'opera! Condividerò il vostro lavoro e le vostre conoscenze ulteriormente, e oltre l'Italia.

Penso che il workshop sia stato impostato e gestito in modo funzionale a guidare bene i partecipanti in tutte le fasi. Avrei trovato utile che tutti i partecipanti, soprattutto quelli che conoscevano bene l'area di studio, avessero partecipato con continuità a tutte le attività incluso il sopralluogo. Ad ogni modo, il sopralluogo è stato ben condotto e molto interessante da un punto di vista di non conoscitore della città. Il sopralluogo ha inoltre fatto sì che la maggior parte delle proposte di intervento si concentrassero all'interno del centro storico poiché erano state viste più da vicino. è venuta meno in questo senso la visione più strategica e a scala vasta che le mappe di valutazione avrebbero consentito di svolgere, ma questo non incide sugli ottimi risultati del workshop: lo segnalo solo come punto di vista legato anche agli interessi personali di ricerca.

Attività lavorativa

14 risposte



Autorizzazione trattamento dati per attività di studio, ricerca e didattica. I dati potranno essere elaborati in forma aggregata e anonima dal Prof Mi...a, ma i dati non saranno divulgato in alcun modo.

14 risposte