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Computational Science and Its Applications – ICCSA 2024 Workshops

Hanoi, Vietnam, July 1–4, 2024
Proceedings, Part VI

6 Part VI



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Preface

These 11 volumes (LNCS volumes 14815–14825) consist of the peer-reviewed papers from the 55 Workshops of the 2024 International Conference on Computational Science and Its Applications (ICCSA 2024) which took place during July 1–4, 2024 in Hanoi (Vietnam). The peer-reviewed papers of the main conference tracks are published in a separate set consisting of two volumes (LNCS 14813–14814).

The conference was held in a hybrid form, with some participants present in person, hosted in Hanoi, Vietnam, by the Thuy Loi University. We enabled virtual participation for those who were unable to attend the event, due to logistical, political and economic problems, by adopting a technological infrastructure based on open source software (jitsi + riot), and a commercial Cloud infrastructure.

ICCSA 2024 was another successful event in the International Conference on Computational Science and Its Applications (ICCSA) conference series, previously held in Athens, Greece (2023), Malaga, Spain (2022), Cagliari, Italy (hybrid with few participants in presence in 2021 and completely online in 2020), whilst earlier editions took place in Saint Petersburg, Russia (2019), Melbourne, Australia (2018), Trieste, Italy (2017), Beijing. China (2016), Banff, Canada (2015), Guimaraes, Portugal (2014), Ho Chi Minh City, Vietnam (2013), Salvador, Brazil (2012), Santander, Spain (2011), Fukuoka, Japan (2010), Suwon, South Korea (2009), Perugia, Italy (2008), Kuala Lumpur, Malaysia (2007), Glasgow, UK (2006), Singapore (2005), Assisi, Italy (2004), Montreal, Canada (2003), and (as ICCS) Amsterdam, The Netherlands (2002) and San Francisco, USA (2001).

Computational Science is the main pillar of most of the present research, industrial and commercial applications, and plays a unique role in exploiting ICT innovative technologies, and the ICCSA conference series have been providing a venue to researchers and industry practitioners to discuss new ideas, to share complex problems and their solutions, and to shape new trends in Computational Science. As the conference mirrors society from a scientific point of view, this year's undoubtedly dominant theme was the machine learning and artificial intelligence and their applications in the most diverse economic and industrial fields.

The ICCSA 2024 conference is structured in 6 general tracks covering the fields of computational science and its applications: Computational Methods, Algorithms and Scientific Applications – High Performance Computing and Networks – Geometric Modeling, Graphics and Visualization – Advanced and Emerging Applications – Information Systems and Technologies – Urban and Regional Planning. In addition, the conference consisted of 55 workshops, focusing on very topical issues of importance to science, technology and society: from new mathematical approaches for solving complex computational systems, to information and knowledge in the Internet of Things, new statistical and optimization methods, several Artificial Intelligence approaches, sustainability issues, smart cities and related technologies.

In the Workshops proceedings we accepted 281 full papers, 17 short papers and 2 PhD Showcase papers. In the Main Conference Proceedings we accepted 53 full papers, 6 short papers and 3 PhD Showcase papers from 207 submissions to the General Tracks of the conference (acceptance rate 30%). We would like to express our appreciation to the workshops chairs and co-chairs for their hard work and dedication.

The success of the ICCSA conference series in general, and of ICCSA 2024 in particular, vitally depends on the support of many people: authors, presenters, participants, keynote speakers, workshop chairs, session chairs, organizing committee members, student volunteers, Program Committee members, Advisory Committee members, International Liaison chairs, reviewers and others in various roles. We take this opportunity to wholehartedly thank them all.

We also wish to thank our publisher, Springer, for their acceptance to publish the proceedings, for sponsoring part of the best papers awards and for their kind assistance and cooperation during the editing process.

We cordially invite you to visit the ICCSA website https://iccsa.org where you can find all the relevant information about this interesting and exciting event.

July 2024

Osvaldo Gervasi
Beniamino Murgante
Chiara Garau

Welcome Message from Organizers

After the very hard times of COVID, ICCSA continues its successful scientific endeavors in 2024, hosted in Hanoi, Vietnam. This time, ICCSA moved from the Mediterranean Region to Southeast Asia and was held in the metropolitan city of Hanoi, the capital of Vietnam. Hanoi is a vibrant urban environment known for the hospitality of its citizens, its rich history, vibrant culture, and dynamic urban life. Located in the northern part of the country, Hanoi is a bustling metropolis that combines the old with the new, offering a unique blend of ancient traditions and modern development.

ICCSA 2024 took place in a secure environment, allowing for safe and vibrant in-person participation. Combined with the active engagement of the ICCSA 2024 scientific community, this set the stage for highly motivating discussions and interactions regarding the latest developments in computer science and its applications in the real world for improving communities' quality of life.

Thuyloi University, also known as the Water Resources University, is a prominent institution in Hanoi, Vietnam, with a strong reputation in engineering and technical education, particularly in water resources and environmental engineering. In recent years, the University has expanded its academic offerings to include computer science, reflecting the growing importance of technology and digital skills in all sectors. This year, Thuyloi University had the honor of hosting ICCSA 2024. The Local Organizing Committee felt the burden and responsibility of such a demanding task and put all necessary energy into meeting participants' expectations and establishing a friendly, creative, and inspiring scientific and social/cultural environment that allowed for new ideas and perspectives to flourish.

Since all ICCSA participants, whether informatics-oriented or application-driven, realize the tremendous advancements in computer science over the last few decades and the huge potential these advancements offer in coping with the enormous challenges of humanity in a globalized, 'wired,' and highly competitive world, the expectations for ICCSA 2024 were high. The goal was to successfully match computer science progress with communities' aspirations, achieving progress that serves real, place- and people-based needs and paves the way towards a visionary, smart, sustainable, resilient, and inclusive future for both current and future generations.

On behalf of the Local Organizing Committee, I would like to sincerely thank all of you who contributed to ICCSA 2024.

Nguyen Canh Thai

Organization

ICCSA 2024 was organized by Thuyloi University (Vietnam), the University of Perugia (Italy), the University of Basilicata (Italy), Monash University (Australia), Kyushu Sangyo University (Japan), the University of Minho (Portugal), and the University of Cagliari (Italy).

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Evaluating Inner Areas Potentials (EIAP 2024)

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Econometrics and Multidimensional Evaluation of Urban Environment (EMEUE 2024)

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Environmental, Social, Governance of Energy Planning (ESGEP 2024)

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Ecosystem Services in Spatial Planning for Resilient Urban and Rural Areas (ESSP 2024)

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Ethical AI Applications for a Human-Centered Cyber Society (EthicAI 2024)

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14th International Workshop on Future Computing System Technologies and Applications (FiSTA 2024)

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Toshihiro Yamauchi	Okayama University, Japan
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Geographical Analysis, Urban Modeling, Spatial Statistics (Geog-An-Mod 2024)

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Andreas Fricke	Hasso-Plattner-Institut für Digital Engineering, Germany
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Geomatics for Resource Monitoring and Management (GRMM 2024)

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International Workshop on Information and Knowledge in the Internet of Things (IKIT 2024)

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Regenerating Brownfields Enhancing Urban Resilience Appeal (INFERENCE 2024)

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International Workshop on Territorial Planning to Integrate Risk and Urban Ontologies (IWPRO 2024)

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MaaS Solutions for Airports, Cities and Regional Connectivity (MaaS 2024)

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Martina Sinatra	University of Cagliari, Italy
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Development of Urban Mobility Management and Risk Assessment (MAINTAIN 2024)

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Multidimensional Evolutionary Evaluations for Transformative Approaches (MEETA 2024)

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Building Multi-dimensional Models for Assessing Complex Environmental Systems (MES 2024)

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Models and Indicators for Assessing and Measuring the Urban Settlement Development in the View of Zero Net Land Take by 2050 (MOVEto0 2024)

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4th Workshop on Privacy in the Cloud/Edge/IoT World (PCEIoT 2024)

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Scientific Computing Infrastructure (SCI 2024)

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Downscale Agenda 2030 (SDGscale 2024)

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Maria Ronza	University of Naples, Federico II, Italy
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Socio-Economic and Environmental Models for Land Use Management (SEMLUM 2024)

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Paola Amoruso	LUM, Italy

Ports of the Future - Smartness and Sustainability (SmartPorts 2024)

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Marco Petrelli	Roma Tre University, Italy

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Maria Ronza	University of Naples, Federico II, Italy
Massimiliano Bencardino	University of Salerno, Italy

Smart Transport and Logistics - Smart Supply Chains (SmarTransLog 2024)

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Enrico Dagostini	University of Malta, Malta
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Luca Toneatti	University of Trieste, Italy
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Smart Tourism (SmartTourism 2024)

Workshop Organizers

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Massimiliano Bencardino	University of Salerno, Italy

Sustainable Evolution of Long-Distance Freight Passenger Transport (SOLIDEST 2024)

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Luigi Dall'Olio	University of Cantabria, Spain
Antonio Russo	University of Enna Kore, Italy

Sustainability Performance Assessment: Models, Approaches, and Applications Toward Interdisciplinary and Integrated Solutions (SPA 2024)

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Temporary Real Estate Management: Approaches and Methods for Time-Integrated Impact Assessments and Evaluations (TREAT 2024)

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ICCSA 2024 took place on the main campus of Thuyloi University in Hanoi, Vietnam.



Plenary Lectures

Harnessing Artificial Intelligence for Enhanced Spatial Analysis of Natural Hazard Assessments



Prof. Dr. Biswajeet Pradhan

Director - Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS), School of Civil and Environmental Engineering, Faculty of Engineering and IT, University of Technology Sydney, Australia

Abstract. In the realm of natural hazard assessments within spatial domains, the advent of Artificial Intelligence (AI) represents a paradigm shift, revolutionizing the way we conceptualize, model, and interpret environmental risks. This keynote address illuminates the profound impact of AI technologies, particularly machine learning algorithms and data-driven approaches, in reshaping our understanding and prediction capabilities concerning natural disasters.

By assimilating and scrutinizing vast spatial datasets, AI-driven models offer unparalleled accuracy and efficiency, facilitating timely and precise hazard assessments. Real-time processing of geospatial information not only enables rapid predictions but also forms the cornerstone of proactive disaster management strategies. Furthermore, AI's capacity lies in its adeptness at deciphering intricate spatial patterns inherent to natural hazards, unraveling subtle cues and previously unnoticed correlations within the data fabric.

This keynote delves into how AI's nuanced interpretation, coupled with advanced algorithms, elevates hazard modeling, providing deeper insights into the spatial dynamics of environmental risks. By augmenting traditional methodologies and revealing hidden patterns, AI fosters comprehensive risk assessments, fostering informed decision-making processes. The fusion of AI and natural hazard assessments in spatial domains heralds a more resilient approach to disaster preparedness and response.

Join us in embracing this transformative era, where AI's sophisticated modeling techniques and precise spatial interpretations converge, heralding proactive and effective mitigation strategies amidst the ever-evolving landscape of environmental challenges.

Short Bio. Distinguished Professor Dr. Biswajeet Pradhan is an internationally established scientist in the field of Geospatial Information Systems (GIS), remote sensing and image processing, complex modelling/geo-computing, machine learning and soft-computing applications, natural hazards and environmental modelling. He is the Director of the Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS) at the Faculty of Engineering and IT at the University of Technology, Sydney (Australia). He was listed as the World's Most Highly Cited Researcher by the Clarivate Analytics Report for five consecutive years, 2016–2020, as one of the world's most influential minds.

He ranked number one (1) in the field of "Geological & Geomatics Engineering" during the calendar year 2021–2023, according to the list published by Stanford University Researchers, USA. This list ranks the world's top 2% most highly cited researchers based on Scopus data. In 2018–2020, he was awarded as World Class Professor by the Ministry of Research, Technology and Higher Education, Indonesia. He is a recipient of the Alexander von Humboldt Research Fellowship from Germany. Between 2015–2021, he served as "Ambassador Scientist" for the Alexander Humboldt Foundation, Germany.

Professor Pradhan has received 58 awards since 2006 in recognition of his excellence in teaching, service and research. Out of his more than 850 articles (Google Scholar citation: 70,000, H-index: 129), more than 750 have been published in science citation index (SCI/SCIE) technical journals. He has authored/co-authored ten books and thirteen book chapters.

Software Engineering Research in a New Situation



Prof. Carl K. Chang

Professor Emeritus, Iowa State University, USA

Abstract. With the rise of Generative Artificial Intelligence (GAI), epitomized by Large Language Models (LLMs), a profound shift has unfolded in software engineering research. In this presentation, I will traverse my four-decade journey in software engineering research, focusing on situational awareness in the era of the Internet of Things (IoT). I have witnessed the turbulence brought forth by the AI community that demands changes in our approaches. Meanwhile, owing to the pervasiveness of services computing, services became the first-class citizen in modern-day software engineering methodologies.

I argue that situational awareness must permeate the entire lifecycle to consistently deliver software services that align with the dynamic needs of users and the ever-evolving environments. I will elucidate this argument by reviewing the Situ framework, offering a comprehensive illustration of my perspective. Furthermore, I will outline my vision regarding the formidable research challenges considering the rapidly shifting landscape dominated by an irresistible and profoundly disruptive generative AI tsunami.

Short Bio. Carl K. Chang is a former department chair and Professor Emeritus of Computer Science at Iowa State University. His research interests include requirements engineering, net-centric computing, situational software engineering and digital health. Chang was the 2004 President of the IEEE Computer Society. Previously he served as the Editor-in-Chief for IEEE Software (1991–1994), and as the Editor-in-Chief of IEEE Computer (2007–2010). He was the 2012 recipient of the Richard E. Merwin Medal from the IEEE Computer Society. Chang is a Life Fellow of IEEE, a Fellow of AAAS, and a Life Member of the European Academy of Sciences (EurASc).

Interpretability and Privacy Preservation in Large Language Models (LLMs)



Prof. My Thai

University of Florida (UF) Research Foundation Professor
Associate Director of UF Nelms Institute for the Connected World

Abstract. Large Language Models (LLMs) have transformed the AI landscape, captivating researchers and practitioners with their remarkable ability to generate human-like text and perform complex tasks. However, this transformative power comes with a set of critical challenges, particularly in the realms of interpretability and privacy preservation. In this keynote, we embark on an exploration of these pressing issues, shedding light on how LLMs operate, their limitations, and the strategies we can employ to mitigate risks. We begin by examining the interpretability in LLMs, which often function as enigmatic "black boxes." Their complex neural architectures make it challenging to understand how they arrive at specific outputs. This lack of transparency raises questions of trust and accountability. When deploying LLMs in real-world applications—whether for chatbots, content generation, or decision-making—it becomes crucial to demystify their decision paths.

We will use explainable AI (XAI) to offer faithful explanations, from the black-box to white-box models, and from feature-based [1, 2] to neuron circuits-based [3, 4] explanations. By visualizing attention mechanisms, feature importance, and saliency maps, we empower users to comprehend LLM predictions. XAI not only fosters trust but also encourages responsible utilization of LLMs.

We next turn our attention to one of the utmost concerns and challenges: data privacy. LLMs process vast amounts of data, raising risks of data leakage, model inversion, the right to be forgotten, and inadvertent exposure of sensitive information. Furthermore, the integration of LLMs into diverse applications also significantly brings these challenges to the next level [5]. This talk explores strategies to protect privacy, including differential privacy, federated learning, and data encryption.

Short Bio. My T. Thai is a University of Florida (UF) Research Foundation Professor, Associate Director of UF Nelms Institute for the Connected World, and a Fellow of IEEE and AAIA. Dr. Thai is a leading authority who has done transformative research in Trustworthy AI and Optimization, especially for complex systems with applications to healthcare, social media, critical networking infrastructure, and cybersecurity. The results of her work have led to 7 books and 350+ publications in highly ranked international journals and conferences, including several best paper awards from the IEEE, ACM, and AAAI.

In responding to a world-wide call for responsible and safe AI, Dr. Thai is a pioneer in designing deep explanations for black-box ML models, while defending against explanation-guided attacks, evident by her Distinguished Papers Award at the Association for the Advancement of Artificial Intelligence (AAAI) conference in 2023. At the same year, she was also awarded an ACM Web Science Trust Test-of-Time award, for her landmark work on combating misinformation in social media. In 2022, she received an IEEE Big Data Security Women of Achievement Award. In 2009, she was awarded the Young Investigator (YIP) from the Defense Threat Reduction Agency (DTRA), and in 2010 she won the NSF CAREER Award. She is presently the Editor-in-Chief of the Springer Journal of Combinatorial Optimization and the IET Blockchain Journal, and editor of the Springer book series Optimization and Its Applications.

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Contents – Part VI

International Workshop on Information and Knowledge in the Internet of Thing (IKIT 2024)

Analysis and Simulation of an IoT System for Measuring Soil Moisture in Avocado Plantations 3
Carlos Bustamante, Felipe A. Lopez, Ruben Bustamante-Encina, Diego Fuentealba, and Gustavo Gatica

Charting the Path of Reading Development: A Study on the Importance and Effective Strategies for Reading in Early Ages Based on Technology 18
Veronica Torres Illescas, Priscila Villacrés Prieto, Jenniffer Román Cabrera, and Augusto Bernal Párraga

A High-Throughput FPGA-Based Elliptic Curve Digital Signature Core for IoT Edge Platforms 31
Cuong Pham-Quoc and Pham Le Song Ngan

Internet of Things for Plastic Bottle Recycling: A Case Study for Salinas 44
Maria Campuzano, Junior Figueroa, and Marcia Bayas

Evaluation of a Fintech Sales Synthetic Data Generation Model Using a Generative Adversarial Network 56
Felipe A. Lopez, Marcia Duran-Riveros, Sebastian Maldonado-Duran, David Ruete, Giannina Costa, Jairo R. Coronado-Hernandez, and Gustavo Gatica

Hybrid Information Security Framework Based on ISO/IEC 27005:2022 and the NIST Framework for the Ministry of Education of Ecuador (TIC) 71
Jayli De la Torre, Daisy Imbaquingo, and Jaime Llumiquinga

regeneratIng browNFields Enhancing uRban rEsilieNCe appEal (INFERENCE 2024)

Waterfronts in the Straits Port Areas, Between Architecture and Town Planning 89
Celestina Fazia, Giulia Fernanda Grazia Catania, and Clara Stella Vicari Aversa

The Recovery of Disused Infrastructure and Military Areas in Spain and Italy, Contributions to the Regeneration of Territories 107
Celestina Fazia, Giulia Fernanda Grazia Catania, and Federica Sortino

A Valuable Brownfield Site by the Sea Awaiting Regeneration: The Case of the Lipari Pumice Quarries 123
Clara Stella Vicari Aversa

Contexts of Reuse and Regeneration. Defense Sites and Disused Infrastructure in Coastal Areas 141
Celestina Fazia, Kh Md Nahiduzzaman, Hassan Radoine, and Tiziana Campisi

The Role of Beauty in the Sustainable Regeneration of the Historical Centres: The Upper Town of Bergamo 153
Alessio Cardaci and Antonella Versaci

Territorial Dynamics and Community Resilience: Transient Housing in Post-earthquake in Al Haouz Rural Regions in Morocco 171
Kaoutare Amini Alaoui, Hassan Radoine, and Kh. Md. Nahiduzzaman

The Landscape from Architecture to the City: Strategies and Methods to Regenerate Through Design 184
Alessandro Barracco, Celestina Fazia, Maurizio Oddo, Antonella Versaci, and Clara Stella Vicari Aversa

International Workshop on Territorial Planning to Integrate Risk and Urban Ontologies (IWPRO 2024)

Enhancing Urban Resilience Strategic Planning with MetaSWOT in Tehran's Historic Residential Districts 205
Romina Nikfarjam, Radman Dastranj, Nastaran Esmaeilpour Zanjani, and Naghmeh M. Lima

Gamification: A Catalyst to Achieve Carbon-Neutral Cities 226
Naghmeh Mohammadpourlima, Mikael Nygård, and Mehdi P. Heris

Analysis of Seismic Risk and Vulnerability of the Historical Context of Tehran with Emphasis on Resilience Zoning 244
Seyed Ali Razavian Amrei, Ghazalhe Goodarzi, and Nastaran Esmaeilpour Zanjani

Supporting Global Knowledge Concerning Risk Domain: Ontologies Put into Practice 256
Caterina Pietra, Beniamino Murgante, Elisabetta Maria Venco, and Roberto De Lotto

Architectural Design Strategies and Tactics as Driver of Critical Awareness: A Research by Design Application for Vulnerable Communities in Ciudad Juárez 273
Tiziano Cattaneo and Emanuele Giorgi

The Integration of Decarbonization and Resilience Strategies in Shaping Sustainable Cities 291
Naghmeh Mohammadpourlima, Xiaoshu Lü, Mikael Nygård, and Nebiyu Girgibo

MOdels and Indicators for Assessing and Measuring the Urban Settlement DeVElopment in the View of ZERO Net Land Take by 2050 (MOVEto0 2024)

Planning Without Shared Strategies. Impacts and Perspectives Along the Abruzzo Adriatic Coastal Belt 309
Emilio Marziali, Annamaria Felli, Chiara Cattani, and Francesco Zullo

Investigating Avalanche Risk Impact on Accommodation Facilities in the Municipalities of Abruzzo Region 323
Sara Pietrangeli, Donatella Guisa, Lorena Fiorini, and Lucia Saganeiti

Multidimensional Evolutionary Evaluations for Transformative Approaches (MEETA 2024)

A Data-Driven Approach to Monitor Sustainable Development Transition in Italian Regions Through SDG 11 Indicators 337
Giuliano Poli, Stefano Cuntò, and Eugenio Muccio

Assemblages for Cultural Heritage: A Methodological Approach of Heritage-Driven Enhancement 356
Sveva Ventre and Maria Cerreta

A Decision Support System for Cultural and Territorial Infrastructures: A Place-Based and Community-Driven Strategy in Inner Italy 373
Benedetta Grieco, Maria Somma, Maria Lucia Raiola, Sabrina Sacco, Piero Zizzania, and Maria Cerreta

A Data-Driven Design Approach for Multi-scale Green Infrastructure Design: Integrating Landscape Connectivity and Phytoremediation in the Piedmont Region (IT) 388
Daniele Cannatella, Max van der Waal, and Francesca Rizzetto

Introducing Principles of Antifragility in World Heritage Management Evaluation Tools: The Case of City of Vicenza and Palladian Villas of the Veneto 406
Ivan Blečić, Maria Carla Saliu, Patrizia Borlizzi, and Alessandro Portinaro

A Methodological Approach for Activate a Community-Based Archive as a Decision-Support System in Urban Regeneration Processes 421
Maria Somma, Ludovica La Rocca, and Caterina Loffredo

Author Index 437

International Workshop on Information and Knowledge in the Internet of Thing (IKIT 2024)

Analysis and Simulation of an IoT System for Measuring Soil Moisture in Avocado Plantations

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Abstract. Modern technologies have benefited agriculture and are used in various agricultural activities, mainly irrigation, to mitigate water scarcity problems. Water scarcity is of particular concern in avocado cultivation due to its water-intensive nature. This study proposes the use of an Internet of Things (IoT) system for avocado cultivation to enable farmers to identify problems and take preventive measures, thus improving crop productivity. The IoT system used data collected from an avocado plantation in Chile. Factors affecting the yield of this crop were studied to validate the proposed system, in addition to simulating harvesting operations, thus demonstrating the relevance of this technology for modern agriculture. This study demonstrates the feasibility of using a low-cost IoT architecture in precision agriculture, thus improving its performance, as well as the importance of collecting data that affect this agriculture in order to support the development of crops through simulations. The conclusions show the need to create an ecosystem that allows the implementation of these technologies, which implies strengthening capacities in terms of knowledge and communication infrastructure, especially considering the rugged terrain of avocado plantations in Chile.

Keywords: Smart Water Management · Smart Agriculture · Precision Irrigation · IoT Platform

1 Introduction

Agricultural activities primarily consume largest amounts of freshwater globally [1], making water scarcity a social and political problem that strongly impacts rural areas in particular [2]. In Chile, this consumption reaches approximately 80%, making it one

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of the 30 countries with the highest risk of water scarcity in the world [3]. Thus, water usage in irrigation must be optimized, particularly when the exact amount of water consumption for each planting line remains unknown.

Avocado farming occupies approximately 32,000 ha (10.8%) of the cultivated area and yields 220 thousand tons of crop, making it one of the most important fruit trees in Chile [4]. The avocado crop maintains high-quality standards, and various technological innovations, as well as drip or sprinkler irrigation are used in their farming [5].

Pruning, soil quality, climate, irrigation, and fertilization are some factors that directly affect the quality and yield of avocados. Therefore, significant efforts, including the use of technology, have been made to improve and optimize these processes to cater to the conditions of each field and facilitate optimal use of resources. Avocados are cultivated mainly in flat areas and on hillsides. In general, the soils where avocado trees are planted are shallow, with very variable textures, low organic matter content, and medium fertility [6]. In terms of climate, frost affects the growth of fruit and shoots on the tree, whereas high temperatures, particularly during the flowering period or when the fruit begins to grow, cause flower drop and fruit burn [7]. Moreover, avocado farming is a highly water- and energy-intensive process and consumes between 7 and 13 thousand cubic meters of water per hectare per year and approximately 400 L of water for each kilo of avocado produced [8].

Avocado trees are sensitive to excess and/or lack of water, and the size of the fruit is proportional to the amount of water consumed. Therefore, the amount of water available for irrigation must be quantified and optimized to meet the characteristics and needs of each crop [9]. Intelligent or precision irrigation (PI) systems are fundamental to guaranteeing good crop harvests [10, 11]. PI is an irrigation management approach, wherein crops are supplied with the required nutrients and water at the desired time, frequency, duration, and volume, thereby improving the crop yield and ensuring efficient water use [12]. This is achieved via data collection (weather, soil type, irrigation, etc.), information processing, efficient irrigation management, and technologies for online detection of problems and automatic control [13].

The Internet of Things (IoT) can be suitably used to address the issues with PI; however, the solution depends on each context and available resources [14].

Herein, an IoT system is proposed to detect the soil moisture content within 1 m of soil depth using moisture sensors that are installed in a trial pit created near the root of the plant and at different depths of 30, 60, and 90 cm. Farmers can proactively identify issues using a mobile application and/or web system and take preventive measures in areas with higher and lower water retention throughout the season. Accordingly, irrigation can be controlled or ceased, as the soil temperature and moisture change linearly over time. Thus, water consumption can be reduced and crop yield per season can be improved. The aim is to investigate whether crop productivity can be improved by monitoring the soil conditions using underground sensors with IoT technology taking into account the climatological aspects of the agricultural sector.

The importance of communication in IoT systems has been recognized [14, 18], but previous research has not considered the specific needs of these configurations, especially in rough terrain or on hillsides [23]. Thus, the implementation required the

incorporation of technologies that would allow for better communication performance with lower data latency. This situation should be considered in future research.

The remainder of this paper is organized as follows. Section 2 presents the literature review and discusses some main existing applications. Sections 3 and 4 present the methodology and development. Section 5 cover preliminary results and discussion, and Sect. 6 concludes the study.

2 Related Work

IoT allows connecting physical elements via different devices to the Internet. It starts from simple things, such as light bulbs, doors, recording cameras, to more complex elements such as health devices, traffic lights, cars and even linking different devices to form smart cities [15]. This interconnectivity is achieved by integrating sensors that collect and transmit data to the Internet, generally via wireless networks [16]. IoT has been successfully implemented in different sectors such as logistics, transportation, health, homes, and agriculture [16–18]. Although its use in agriculture is recent, most IoT systems have focused on monitoring and controlling risks [19]. For instance, an IoT-based irrigation management platform [20] was developed to increase water productivity in main crops. Additionally, a platform for precision agriculture and ecological monitoring with private features was designed using several sensor nodes deployed in various facilities [21].

Another study also focused on improving the yield classification and prediction algorithms that use data obtained via IoT [22], thus realizing the potential of this technology.

A robotic system was also proposed in India to detect soil temperature and moisture [23] by transmitting these data via an IoT platform. Manual controls were employed using a mobile application and Bluetooth to control the robotic system in real-time. Other studies were also conducted to evaluate the benefits of using IoT in agriculture [24, 25].

Developing low-cost, more stable and efficient systems is now an opportunity for innovation [26, 27]. Integrating IoT into proprietary systems and/or public clouds is becoming more and more recurrent [28]. The integration of peripherals and other software components contributes to rapid prototyping in order to make informed decisions, both in terms of system quality and costs [29].

Table 1 shows different systems that are currently employed in the agriculture sector. Kilimo (https://kilimoagtech.com/) is an effective irrigation management platform that connects weather stations in an area with data entered by the user and calculates the evapotranspiration of plants to provide irrigation recommendations. Agri (https://www.agri.cl/) web application is used for managing agricultural activities; it contains modules on irrigation control, climate, and IoT. Instacrops (https://www.instacrops.com/) is a Chilean company oriented toward the development of hardware and software for agriculture by integrating different data sources, artificial intelligence, and computer vision to collect information on key crop parameters. Netafim (https://www.netafim.cl/) focuses on precision irrigation and highlights its own weather stations together with irrigation system sensors. Hermisan (https://hermisan.com/) offers irrigation solutions,

with proprietary plant development by integrating various modules. Agrapp (https://agrapp.cl/) is an application that ensures crop management and works offline; it does not use sensors, climate measurements, or artificial intelligence. Irricontrol (http://www.irricontrol.com.uy/) is a platform that manages a database in real-time using IoT systems and facilitates irrigation planning by running a program selected by the user that indicates the irrigation threshold by permanently updating the soil moisture balance. Aquadaia (http://www.aquadaia.com/) reports on the amount of water needed for the optimal growth of a crop by connecting to the nearest weather station and incorporating various data mining techniques to recommend irrigation options. Orionis (https://orionis-iot.com/) offers products focused on crop management and point solutions for remote irrigation control. Agricultic (https://agricultic.net/) is an IoT platform comprising hardware, software, and applications developed for data acquisition, monitoring, and control of agribusiness processes. It uses multispectral image analysis, data analytics, and field sensors, which together allow the system to monitor climate, soil, and water quality, among other factors.

Table 1. Analysis and comparison of current IoT platforms on the market.

Functional features	A	B	C	D	E	F	G	H	I	J
Web access	X	X	X	X	X	X	X	X	X	X
APP version	X	X	X		X	X	X	X	X	X
Desktop version				X	X					X
Role and profile management	X	X	X	X	X	X	X	X	X	X
Real-time information	X		X	X	X		X	X	X	X
Creation/modification of customized measurements	X	X		X	X	X	X	X	X	X
Customized reports	X	X		X	X	X	X	X	X	X
IoT		X	X	X	X		X	X	X	X
Climate information analysis	X		X	X	X		X	X	X	X
Support	X	X	X	X	X	X	X	X	X	X
Non-functional features										
Customer registration	X	X	X	X	X	X	X	X	X	X
24/7 access	X	X	X	X	X	X	X	X	X	X
Database access	X	X				X	X	X		X
Backups	X	X	X	X	X	X	X	X	X	X
Data download from the cloud	X		X		X	X	X		X	X
99.9% uptime	X	X	X	X	X	X	X	X	X	X
Data import from external files			X	X	X					

Note: A: Kilimo; B: Agri; C: Instacrops; D: Netafim; E: Hermisan; F: Agrapp; G: Irricontrol; H: Aquadaia; I: Orionis; J: Agricultic. Source: Own elaboration based on information from websites

These aforementioned solutions were developed on complex architectures using applications oriented toward irrigation systems for large-scale farming. They also have high implementation costs because of the use of weather stations, telemetry for controlling irrigation and fertilizer supply based on the chemical content in the soil.

In contrast, the solution proposed herein can be modified to suit varying needs and enables the configuration of main parameters based on the geographical characteristics of crops. They are economical and developed using opensource technologies as well as stable and quality components. Thus, it provides farmers with relevant information, using which ideal irrigation and water supply measures can be taken.

3 Methodology

The methodology used for developing the proposed IoT system is designed using metrics that validate the previously defined objectives [30, 31]. The data to be analyzed were obtained from an avocado plantation in the central zone, near the town of Quillota. These data were the actual measurements of soil relative humidity, UV intensity, ambient temperature, and wind speed and direction recorded from August 2019 to March 2020 from a weather station. The avocado plantation spanned 2.5 ha, with approximately 500 avocado trees per ha, with an age of 15 years of maturity. The crop is harvested annually. The land is sandy and irrigated every two days, once or twice a day, using water obtained from a well and an irrigation canal.

This investigation focuses on a specific type of avocado cultivation, with characteristics such as climate and soil type different from those of other regions. Therefore, the factors associated with these regions have been thoroughly studied.

Quality assessment was performed based on the ISO 25000 standard to measure aspects of the product such as data, crop life cycle, and metrics [32–34]. 60% of the established quality attributes in ISO25000 were achieved.

4 Development Process

The methodology used for meeting the proposed objectives is discussed in subsequent sections.

4.1 Relevant Literature Review

A systematic literature search [35–38] was conducted using Google Scholar to incorporate white and gray literature. The inclusion criteria were articles published since 2000, the complete process of avocado cultivation, the influence of land use, determinants of avocado growth, and the use of computer simulation and precision agriculture. Exclusion criteria were articles published before 2017, not considering avocado cultivation, referring to a particular software, and oriented to a particular market (country). The initial search resulted in 918 articles. 37 articles were selected based on the inclusion and exclusion criteria were applied, as shown in Table 2.

Table 2. List of articles analyzed and their corresponding research areas.

Research area	Reference
Avocado tree cultivation	[9, 39–41]
Avocado irrigation	[42, 43]
Irrigation automation	[5, 44, 45]
Precision agriculture	[46–51]
Irrigation technologies	[12, 52–54]
Internet of Things	[18, 19, 37, 38, 55–58]
Telemetry	[59–64]
Machine learning smart irrigation	[65–68]

Three lines of research were identified: automated drip risk systems, water efficiency based on agriculture 4.0, and precision agriculture. Figure 1 shows the sub-areas.

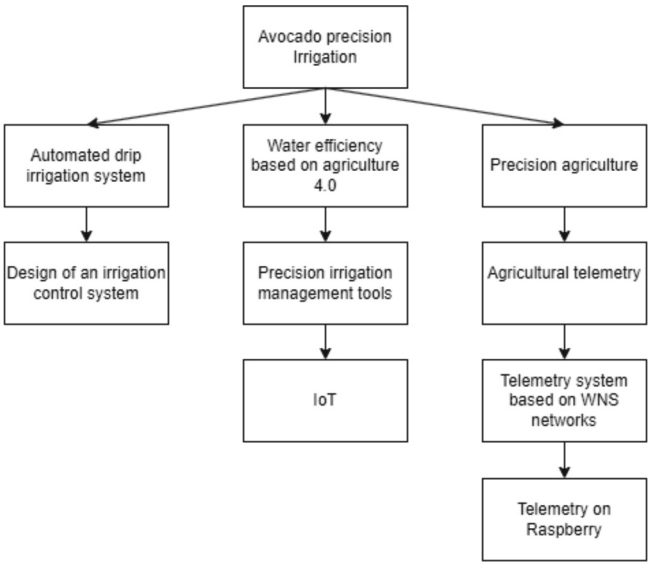

Fig. 1. Main research areas. Source: Own elaboration

The following influencing factors were identified:

Pruning: This process is used to improve productive capacity and fruit size and quality. During the initial years of development, main branches are shaped using three types of pruning: training, fruiting, and restoration.

Irrigation: Avocado farming consumes large amounts of water throughout the year following the water demand curve of the growing area. In Aconcagua Valley, Chile, with a Mediterranean climate, the annual water consumption of the adult avocado trees irrigated

using micro sprinklers varies between low and high localities, fluctuating between 7,000 and 16,000 m^3/ha/year, if a Kc of 0.72 and an Efa of 85% are considered. In this region, part of the water demand is covered by rainfall in June, July, and August. However, 80% of the water demand is covered between October and March.

Soil: The most recommended soils for avocado farming are light-textured, deep, and well-drained. However, clay or clay loam soils can also be used as long as good drainage is ensured. Excess moisture fosters physiological root diseases such as root asphyxia and fungal diseases such as phytophthora cinnamomi [5]. Avocado trees thrive in soils with neutral to slightly acidic pH (5.5–7), as long as salt or sodium accumulation can be prevented. Such accumulations considerably affect crop yield and commonly result in micronutrient deficiencies.

Fertilization: Fertilizers can be used four times during avocado farming, particularly during flowering, fruit setting, and after harvest. This prevents common symptoms caused by nutrient deficiencies such as blackening of vascular bundles in avocados due to lack of potassium, browning of mature leaves due to lack of phosphorus, and yellowing and premature leaf drop due to lack of nitrogen. The crop yields can be improved by addressing nutritional deficiencies or stress as they impact the foliage or leaves of the tree.

Climate: Climate is a vital factor for improved avocado production, both in terms of potential possibilities as well as quality and yield. Frost can cause damage to fruits and trees. During its vegetative development, avocados cannot withstand temperatures below −1.1 °C. However, during winter, they can withstand up to −2 °C or −4 °C depending on the age of the trees. To avoid frost in Chile, avocados are cultivated in soils located on hills with steep slopes, preferably with northern exposure. During flowering and fruit setting, which occur between September and November, daytime temperatures are $\geq$20 °C and >10 °C at night. Lower temperatures during the day or night cause a reduction in fruit setting, particularly in orchards closer to the sea. The base temperature for avocado growth is 12.5 °C–36 °C. The average maximum winter temperatures should be >15 °C for continued growth of avocados. Another climatic factor that affects avocado trees is the wind, which causes fruit drop, breakage, and branch detachment.

Pests: Avocados in Chile are affected by a few diseases. Some isolated cases of fungal and bacterial damage to plants have also been observed. The main phytosanitary issue in Chile is caused by phytophthora cinnamomi, which causes root rot and progressive decay of the tree. Symptoms of such infestations involve the presence of small leaves, yellowish green foliage, leaf drop, semitransparent trees, small fruits, and sunstroke. If the infection is severe, trees may eventually die. This fungus infestation is observed in areas with high soil moisture content and the presence of wounds in the roots.

The irrigation process is simulated, and artificial validation scenarios are created based on parameters such as soil moisture, ambient temperature, avocado tree development stage, soil characteristics (moisture and pH, among others), and irrigation equipment characteristics (actual precipitation intensity of the equipment and percentage of soil wet by the emitters).

4.2 Technological Architecture

Figure 2 shows the proposed IoT architecture comprising a device that collects data related to soil moisture and temperature. These data are then sent to a database in the cloud and processed for visualization by farmers.

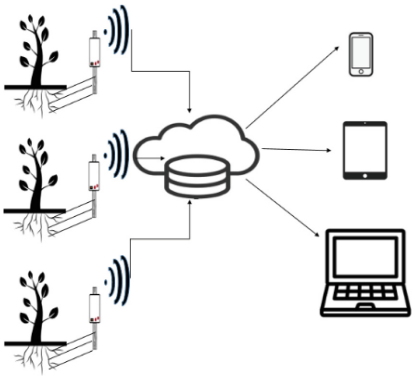

Fig. 2. Proposed architecture. Source: Own elaboration

Python batch processing is performed for transferring information to a new server, from which reports are extracted. Then, simulations are performed, and management reports are delivered using Power BI, Python, and R (Fig. 3).

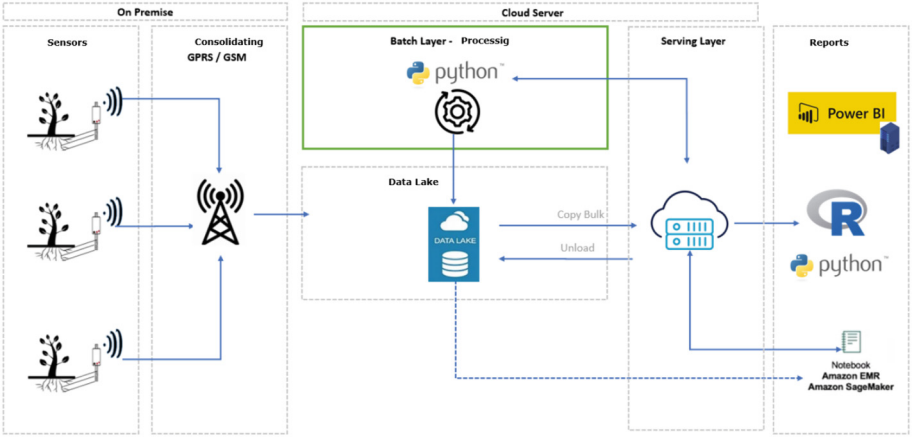

Fig. 3. Technology architecture diagram. Source: Own elaboration

For validation, use cases, specifications, class diagrams, sequence diagrams, and entity-relationship models are generated based on the different software development practices [30, 31] (Figs. 4 and 5).

The following IoT components are considered: Arduino UNO, soil moisture sensor (YL-69), ambient temperature and humidity sensor (DTH11), SIM900D wireless card, and polycrystalline solar panel solar cell.

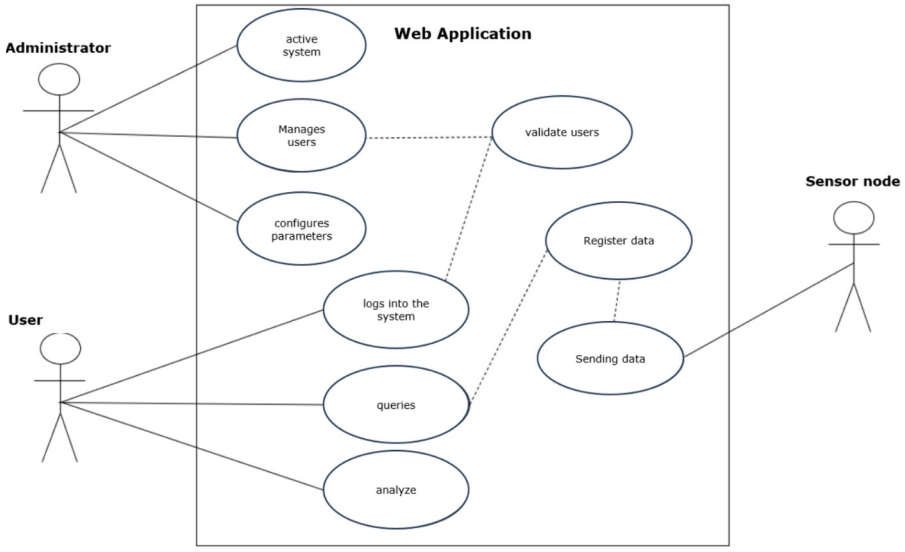

Fig. 4. Example use cases. Source: Own elaboration

4.3 Validation by Discrete Simulation

Discrete simulation reduces the high uncertainty of using various exogenous variables such as environmental variables, weather, frost, and rainfall [69].

Selection of Artificial Validation Scenarios. Seventeen elements are considered essential for the growth and production of all cultivated crops, including avocados [5, 8]. The three essential macronutrients for fruit biomass (roots, trunk, branches, leaves, and fruit) are carbon (C), hydrogen (H), and oxygen (O), and represent 90% of the dry matter of trees. Of these, C is supplied from the atmosphere, which is transformed into carbohydrates via photosynthesis. H and O are provided by water. The essential mineral nutrients for the plant are categorized into macronutrients and micronutrients. Among the macronutrients found in plants, nitrogen (N), potassium (K), and calcium (Ca) are considered primary, whereas phosphorus (P), magnesium (Mg), and sulfur (S) are secondary. Micronutrients include zinc (Zn), manganese (Mn), copper (Cu), iron (Fe), boron (B), molybdenum (Mo), chlorine (Cl), and nickel (Ni). This criterion for differentiating nutrients can lead to confusion, as in extreme cases, the deficit of a given micronutrient can become more important than a macronutrient [5].

Some of the 14 essential mineral elements are supplied via fertilizers due to soil weakness and erosion. Such nutritional deficit is accentuated when the nutrient is not

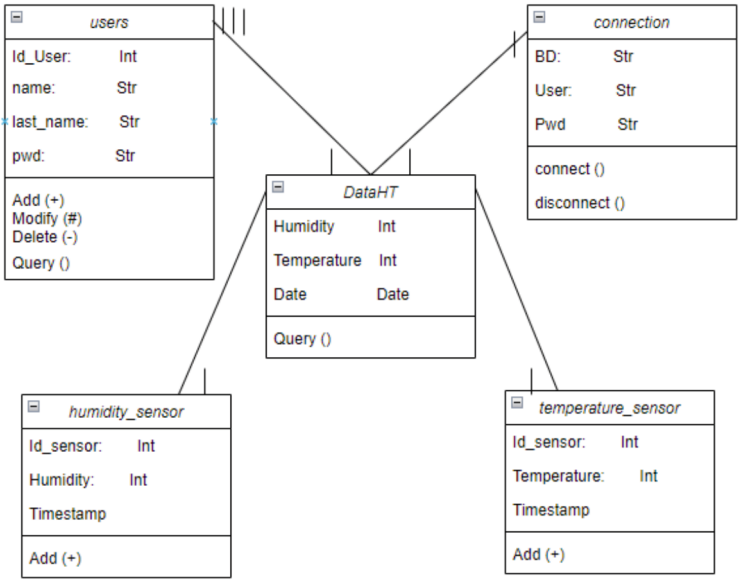

Fig. 5. Example of a class diagram. Source: Own elaboration

sufficiently mobile within the plant and does not reach the strategic site of action, such as buds, flowers, or recently set fruit. In either case, the nutrients will have to be replenished via soil or foliar fertilization. The soils of areas containing avocado plantations, such as the Valparaíso Region, are fertile but lack micronutrients such as Zn, B, and Fe. The aim is to simulate data collection from different IoT devices using simulators in the field of electronic circuit generation and computational systems, and an electrical prototype was developed.

5 Preliminary Results and Discussion

The proposed IoT architecture was developed by modifying a previously reported methodology [70] or via software simulation. The architecture was evaluated based on the ISO 25000 for software quality.

Although a standard IoT infrastructure has not been established [18] such systems are used in avocado agriculture to reduce and optimize water consumption and reduce operating costs. However, their implementation is difficult in terms of infrastructure and trained personnel [71], accounting for a gap in terms of capacity building in this aspect.

The advantage of this IoT system is that it allows real-time data collection for informed irrigation decisions based on the requirements of each farm [24], thus improving performance.

The ability to remotely monitor water usage provides the opportunity to identify potential problems early, such as water stress or leaks in the irrigation system, allowing to anticipate water shortage problems [12, 13].

This paper identifies patterns and trends in PI for establishing long-term farming strategies and planning future farm expenditures related to labor or logistics [10, 11], which have been reviewed in previous literature.

6 Conclusions

The use of IoT in precision agriculture enables irrigation optimization and fosters cost reduction and strategic production planning. However, robust methodologies are required for software simulations, so that the process can be iterated and accurately documented. The planning of crop harvesting process can be simulated using large amounts of data.

The proposed architecture is economical and can therefore be installed in small- and large-scale farms. However, their implementation is limited by communication infrastructure and lack of knowledge regarding its use. In future studies, precision agriculture with IoT can be explored on other crops to compare the effectiveness of methodology and simulations. The scalability of the infrastructure will also be evaluated to enhance the accuracy of conclusions.

To increase the confidence level, larger amounts of data will be required for performing complex simulations. This study focused only on a specific type of avocado crop, with characteristics such as climate and soils different from those of other regions; therefore, an exhaustive review of the factors associated with these regions will be required to replicate the current study.

The limitations of this study are related to the type of avocado chosen and the region in which the implementation was carried out, which, given its specific conditions, does not allow the generalization of the results.

There are also limitations related to the communication infrastructure, which should be considered in the process of implementing these technologies, considering, among other things, the limitations of connectivity and the ruggedness of the terrain.

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Charting the Path of Reading Development: A Study on the Importance and Effective Strategies for Reading in Early Ages Based on Technology

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Abstract. This scientific article explores the transcendental dimension of reading development in early childhood, highlighting its impact on the educational and cognitive training of children. Through a rigorous study, we investigated the importance of reading early in life and evaluated effective strategies to foster a strong reading foundation. From a solid theoretical framework to a carefully designed methodology, our findings shed light on key practices to enhance the love of reading from an early age. This study not only addresses academic relevance but also highlights the connection between early reading and children's holistic development. We conclude by offering valuable practical implications for educators and policymakers, thereby contributing to the understanding and promotion of reading development in early childhood. This work represents a significant contribution to advance knowledge and effective strategies to cultivate competent readers from their first years of life.

Keywords: Reading Development · Effective Strategies · Early Childhood · Technology

1 Introduction

In this context, our study seeks to trace the complex network of factors that influence reading development at an early age. From the analysis of pedagogical theories to the evaluation of teaching strategies, our meticulous methodological approach aims to unravel the secrets of effective teaching and learning in the field of children's reading. Through this scientific inquiry, we aim not only to enrich academic understanding, but also to provide tangible and insightful tools for educators, parents, and professionals involved in shaping young minds. With this work, we aspire to shed light on the path of reading development at an early age, thus contributing to the construction of a solid foundation for the educational future of future generations.

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The existing literature on the importance of reading at an early age is presented as a vast landscape of research and reflections that converge in the unanimous conclusion that reading development in the first years of life establishes the fundamental pillars for educational success and well-being, cognitive and emotional throughout life. Numerous studies have shown that early exposure to reading not only promotes the acquisition of linguistic and cognitive skills, but also acts as an essential catalyst for socio-emotional development. Early interaction with books and storytelling are intrinsically linked to strengthening the emotional bond between parents and children, creating fertile ground for the development of crucial social and emotional skills.

In the academic field, the literature reviewed consistently highlights the positive correlation between reading competence at an early age and future academic performance. Early literacy not only facilitates the assimilation of knowledge in various disciplines, but also nurtures critical thinking and problem solving from an early age. As research advances, the connection between reading at an early age and the development of creative thinking has also been highlighted. Exposure to rich and varied narratives stimulates imagination and creativity, cultivating young minds capable of approaching challenges with insight and originality. In summary, the literature review unequivocally confirms that early reading is not simply a milestone in the educational journey, but rather the seed that germinates in the fertile garden of continuous learning. This analysis sets the stage for the detailed exploration of effective strategies in promoting early childhood reading in our scientific study.

2 Methodology

Research on early reading development has generated various theories and approaches that shed light on the importance of this crucial stage. Next, a theoretical framework with four steps is presented, supporting the scientific study on reading development in young children: document search; research questions; Article selection; and extraction of relevant data.

2.1 Document Search

Theory of Information Processing

Information Processing Theory, supported by studies such as that of Anderson and Clark [1], offers an essential perspective to understand reading development at an early age. This theory postulates that reading is built through a gradual process of information processing, encompassing letter identification, word decoding, and understanding meaning. The process begins with the identification of individual letters. Perfetti *et al.,* [2] has explored how children, in their early stages of learning, develop the ability to recognize and distinguish between different letters.

Word decoding is a crucial milestone. Studies such as Ehri's [3] have examined how children acquire decoding skills, connecting letters with their corresponding sounds and forming the necessary foundations for fluent reading.

Understanding meaning is the ultimate goal. According National Reading Panel [4] research has highlighted the importance of lexical and semantic understanding in the reading process, highlighting how children, from an early age, work towards deep understanding of words and text.

At early ages, there is a focus on the development of basic skills. Studies such as Share [5] have examined the progression of word recognition skills, identifying developmental patterns in children's ability to recognize common words. This scientific analysis supports the Information Processing Theory by showing how the different stages of identification, decoding and comprehension are interconnected in the process of reading development at an early age.

Theory of Constructivism in Reading Development

The Theory of Constructivism, supported by research such as that of Chen [6], offers a valuable perspective on how children actively build their reading comprehension from an early age. From this perspective, reading is conceived as an interactive and social process, where children participate in the active construction of meaning through interaction with texts, experiences and their environment.

The basis of constructivism is the idea that children are not passive recipients of information, but active constructors of their own knowledge [7]. Research by Vygotsky [8] supports how the reading process benefits when children actively participate in the construction of meaning.

The interaction with texts is central to this process. Studies such as Pressley [9] have explored how interaction strategies, such as asking questions during reading, facilitate meaning construction and improve reading comprehension in children.

Participation in Conversations: Conversations about the text are essential. Nystrand's [10] research has highlighted the importance of group discussions and structured conversations about read content to strengthen understanding and meaning construction.

From an early age, children participate in an interactive and social process of meaning construction. Palincsar and Brown's [11] research has highlighted how social interactions, such as peer tutoring, contribute significantly to reading development. This scientific approach supports the Theory of Constructivism by highlighting how active participation, interaction with texts and conversations about content promote the effective construction of meaning in the children's reading process.

Bronfenbrenner Ecological Model considers reading as a phenomenon that develops within an ecological context. Factors such as family, school, and community have a significant impact on reading development. At early ages, the model highlights the importance of an enriching environment that provides literary experiences and emotional support to encourage reading [12].

Dual Processing Model suggests that there are two processing systems involved in reading: one for word recognition and another for understanding meaning. At early ages, it is examined how children develop decoding skills (surface processing) and comprehension (deep processing) simultaneously [13].

Socio-Cultural Reading Theory highlights the influence of culture and social environment on reading development. At early ages, it focuses on how cultural practices and social interaction impact the way children acquire reading skills. It includes aspects such

as storytelling, exposure to different types of texts, and participation in literary practices within the community [14].

Phonic Processing Theory focuses on how children develop phonological awareness, the ability to recognize and manipulate speech sounds. At early ages, how phonological awareness is related to learning to read and the ability to connect letters and sounds is explored [15].

Evidence-Based Reading Theory focuses on the application of evidence-based practices for teaching reading. At early ages, it involves using research-backed teaching methods to develop reading skills, such as systematically teaching phonics and comprehension strategies [16].

These theories, models and concepts provide a comprehensive theoretical framework to understand reading development at an early age, opening the door to the exploration of effective strategies in our scientific research.

The accumulated research in the field of reading at early ages has provided a solid basis for understanding the various aspects of this crucial process. The review of previous studies reveals findings and trends that enrich our understanding and guide the direction of the present research highlighting: the importance of shared; influence of family literacy; evidence-based teaching approaches; impact of oral storytelling; role of phonological awareness; effectiveness of phonics teaching; and role of the literary game.

The relevance and positive impact of shared reading between parents and children have been analyzed in significant research. Notable studies, such as the one carried out by Bus, van Ijzendoorn and Pellegrini [17], highlight the direct connection between shared reading and reading development in childhood. Research indicates that the quality of interaction during shared reading emerges as a key predictor of reading progress in young children. The findings of this study suggest that active parental involvement during reading contributes not only to the enrichment of vocabulary and comprehension, but also to the stimulation of a lasting interest in reading in children. Shared reading is thus presented as a valuable tool to foster a love of reading from the early stages of development [17].

Sénéchal and LeFevre's [18] research has provided valuable exploration of the positive influence of family literacy on children's reading development. This detailed study examined how early exposure to books and reading activities at home is significantly associated with an increase in children's reading skills. Family literacy emerges as a crucial factor that goes beyond the classroom, demonstrating that shared reading experiences and the presence of printed materials in the home environment have a measurable impact on reading progress. The findings support the idea that fostering a literate home environment positively contributes to the early development of reading skills in children [18].

Critical evaluation of research by the National Academy of Sciences, as reviewed by the National Reading Panel in 2000 [4], has shed light on the effectiveness of evidence-based approaches for teaching reading to young children. Explicit instruction in comprehension strategies and guided practice have been highlighted as critical elements in improving reading skills at this crucial stage of development. This review provides solid

scientific support for the implementation of research-backed teaching methods, emphasizing the importance of directly addressing comprehension strategies and providing structured guidance during the process of teaching early reading [4].

Impact of Oral Storytelling:

Significant research, such as the study conducted by Dickinson and Smith [19], has delved into the positive impact of oral storytelling on vocabulary development and reading comprehension in young children. This study examined how exposure to complex, vocabulary-rich narratives significantly contributes to children's cognitive development. Oral storytelling is identified as a key factor in expanding vocabulary and understanding narrative structures, essential elements for reading success. Research by Dickinson and Smith [19] supports the idea that the practice of active, nurturing storytelling can have lasting positive effects on young children's language and reading development.

The crucial role of phonological awareness in learning to read has been the subject of extensive research, supported by significant studies in the field. Wagner and Torgesen [20] conducted extensive research highlighting the close relationship between phonological awareness and the process of learning to read. Their work provides substantial evidence that the ability to manipulate and understand speech sounds is an essential precursor to early reading success. In a similar vein, Bradley and Bryant [21] contribute to this perspective by addressing how phonological awareness directly impacts children's ability to decode words and understand the structure of written language. Both studies underscore the critical importance of developing phonological awareness as an integral part of early instruction to ensure solid progress in learning to read [20, 21].

The effectiveness of phonics teaching has been the subject of numerous studies that support its positive impact on the development of reading skills at early ages. Adams [1], in his influential work, highlights the importance of systematic phonics instruction by demonstrating how the relationship between letters and sounds lays the crucial foundation for initial reading acquisition. This finding has been corroborated in more recent research, such as that carried out by Johnston and Watson [22], who reaffirm the effectiveness of phonics teaching by focusing on the precise connection between letters and their corresponding sounds. These studies highlight the relevance of structured and systematic instruction in phonics as a key strategy for the effective development of reading skills in the initial stages of learning [1, 22].

Research by Wasik and Bond [23] and Neuman [24] has examined how literary play activities, such as story dramatizations, can improve reading comprehension and interest in young children. This review confirms the diversity of factors that influence reading development at early ages and highlights the importance of a holistic approach that integrates various aspects of the educational and family environment. These previous studies provide a solid foundation for our current research, which seeks to expand and contextualize this knowledge in the current educational landscape. In the educational field, teaching reading has become an exciting and dynamic challenge. The implementation of game-based pedagogical strategies has emerged as an innovative approach to stimulate students' interest and active participation. This review thoroughly explores the impact of the game-based approach on the development of reading skills, providing a comprehensive view of its effectiveness and benefits.

In respect to the importance of Reading and the Role of Playful Strategies, reading skills are essential for the academic and personal development of students. As technology advances, it is imperative to adapt our teaching strategies to keep students engaged. Game-based strategies not only offer a refreshing change to the traditional approach, but also address the diverse learning styles present in the classroom.

Game-Based Approach present some benefits: promotion motivation; the development of cognitive skills; and the adaptability to different reading levels (Table 1).

Table 1. Game-Based approach benefits.

Benefits	Description
Promoting Motivation	"The game, being intrinsically motivating, creates an environment conducive to learning, stimulating students' desire to actively participate in reading" [25]
Development of Cognitive Skills	The incorporation of games in the teaching of reading has been shown to strengthen cognitive skills such as attention, memory, and problem solving" [26]
Adaptability to Different Reading Levels	The games allow the difficulty to be adapted according to the reading level of each student, providing a personalized approach and favoring individual progress" [27]

Despite successful strategies in practice is possible highlight the educational crossword games, and the reading roles in simulation games.

Educational Crossword Games is "The creation of crossword puzzles with terms related to the reading content consolidates comprehension and facilitates the retention of information" [28].

In the case of Reading Roles in Simulation Games, "through reading roles, students immerse themselves in contextualized situations, improving their reading comprehension by relating it to practical experiences" [29].

The game-based approach in teaching reading emerges as an effective and engaging strategy. Educators can leverage this methodology to transform students' learning experience, cultivating not only strong reading skills but also a lasting love of reading.

2.2 Research Questions

The design of this study is framed in a descriptive and cross-sectional research. The descriptive nature focuses on providing a detailed analysis of the current situation of early reading instruction, while the transversal nature involves the collection of data at a single point in time.

The target population consists of kindergarten teachers from public schools in the city of Machala, Ecuador. The sample is selected in a representative manner, and the electronic survey is sent to all available preschool teachers in the city.

A questionnaire designed and administered through Google Forms is used. This questionnaire consists of 10 questions specifically formulated to obtain relevant information about teaching reading practices at an early age. The questions cover topics such as teaching methods used, resources available, challenges faced, and perceptions about the effectiveness of the strategies implemented.

The survey is sent electronically to preschool teachers identified in the public schools of Machala. A link accessible via email or electronic messaging is provided.

Teachers have the option to participate voluntarily and provide informed consent to participate in the study before completing the survey.

Data is collected as teachers complete the online survey. Using Google Forms allows for efficient and organized collection of responses.

The data collected is analyzed using statistical tools and descriptive techniques. Tables and graphs are used to present the results in a clear and understandable way.

A detailed interpretation of the results is carried out, highlighting patterns, trends and key findings. Special attention is paid to responses that offer insights into the effectiveness of current reading instruction strategies.

This methodological approach allows us to obtain a comprehensive vision of the teaching practices of reading at an early age in the specific context of the public schools of Ecuador. The use of electronic tools facilitates efficiency in data collection and analysis, guaranteeing the quality and representativeness of the information obtained.

2.3 Article Selection

During the article selection process, filtering criteria were applied with the objective of choosing documents from research databases. These criteria considered aspects such as the relevance of the content, the inclusion of reviews and its relationship with topics such as education, early reading, methodology, technology and related areas. Furthermore, in the searches carried out in the bibliographic databases, an additional filter was incorporated that covered the classification by disciplines such as education, early reading and technology.

2.4 Extraction of Relevant Data

Technology and Reading

In the digital age, the integration of technology into education has significantly transformed the way students interact with reading. This scientific article critically examines the role of educational applications in promoting reading skills, highlighting relevant research and evaluating their impact on reading development.

The Paradigm Shift in Reading

Access to mobile devices and tablets has redefined the way students approach the reading process. Recent research suggests that educational apps can play a critical role in improving reading comprehension and promoting digital literacy [30].

Benefits Identified in Previous Studies: Interactivity and Engagement: “The interactivity of educational applications captures students’ attention, promoting active engagement with the reading material” [6].

Adaptability and Personalization: "Applications that adapt the level of difficulty according to individual abilities improve the learning experience and promote gradual progression in reading competence" [12].

Immediate Feedback: "The immediate feedback provided by the applications allows students to correct errors and improve their understanding efficiently" [13].

Challenges and Ethical Considerations: Despite the obvious benefits, it is crucial to address the challenges associated with the use of technology in education. Student privacy, equity in device access, and quality of digital content are areas that require continued attention [14].

Recommendations for Effective Implementation: Continuous Evaluation: "Educators should regularly evaluate the effectiveness of educational applications, ensuring that they are aligned with pedagogical objectives and student needs" [15].

Teacher Training: "Teacher training in the effective integration of educational applications is essential to maximize the benefits and address the challenges associated with technology in the classroom" [16].

This article highlights the need for continued exploration and critical evaluation of educational applications as tools to improve reading literacy. By thoughtfully embracing technology, the educational community can transform the way students interact with the act of reading.

3 Analysis and Results

In this research, a qualitative approach is used through the collection of data from articles in scientific journals and the survey conducted with 150 preschool teachers, that is, initial education teachers from public schools in Machala Ecuador. The analysis of these data suggests a diversity in the methods and approaches used to teach early reading. Here is a breakdown of each result:

Game-Based Approach (43.4%): The predominance of this approach indicates a significant interest in the integration of playful and participatory elements in the reading teaching process. This method could involve using educational games, interactive activities, and immersive narratives to make learning to read more engaging and effective.

Phonic Method (37%): Like the Phonetic-Syllabic Method, this approach involves teaching the relationship between letters and sounds. This result suggests a preference for methods that focus on phonics as a basis for the acquisition of reading skills. Phonetic-Syllabic Method (36.1%): This method focuses on teaching children to recognize and associate letters or groups of letters with corresponding sounds. The inclusion of this method highlights the importance attributed to decoding and phonics as essential components of learning to read. The significant presence of multiple approaches reveals the understanding that children may have diverse learning styles, and combining strategies may be key to addressing their individual needs. This analysis provides a balanced view of the methodologies applied in teaching reading at an early age, this can be seen in Fig. 1.

The analysis of these data reveals that the most used strategies to promote reading comprehension in children in their early stages of learning are Open Questions, with 51.6%. They are followed by Role Games, with 50.2%, and the Use of Manipulable

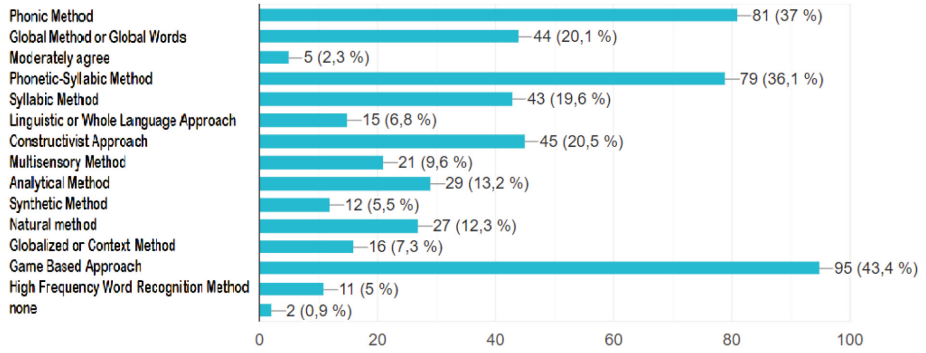

Fig. 1. Reading Teaching Strategies What main method or approach do you use to teach early reading?

Materials, with 41.6%. These results indicate that there is a significant emphasis on the practical and experiential approach to promoting reading comprehension in children. The use of Role Plays suggests the incorporation of playful and participatory activities that actively involve children in situations related to reading. Open Questions indicate a deeper analysis approach, encouraging reflection and verbal expression. Furthermore, the Use of Manipulative Material suggests the integration of tangible resources to improve comprehension through the physical manipulation of objects related to the reading content. This diverse set of strategies reflects the importance of approaching reading comprehension from multiple perspectives, adapting to the unique nature of each child and providing a rich and varied learning environment, this can be seen in Fig. 2.

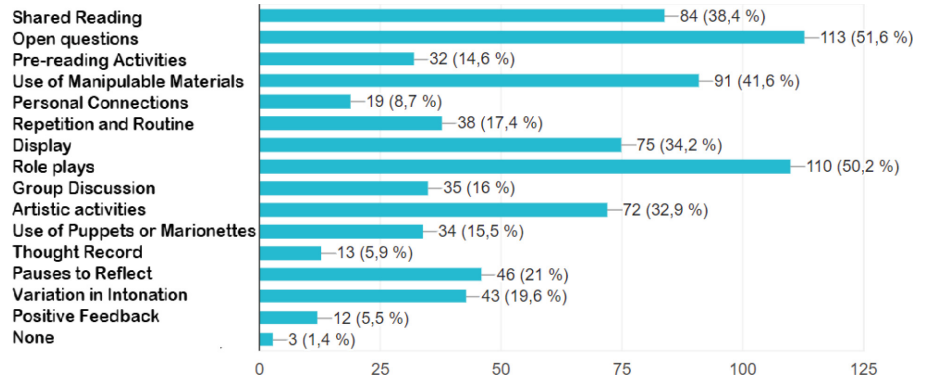

Fig. 2. Promotion of Reading Comprehension. What strategies do you use to promote reading comprehension in children in their early stages of learning?

The analysis of this data in relation to the use of technology in teaching reading reveals a trend towards the incorporation of digital tools. Here is a breakdown of each

result: Educational Applications (41.6%): The prevalence of this category suggests substantial interest in the integration of educational applications to support the reading teaching process. These apps could range from those designed to improve phonics to those that promote reading comprehension through interactive activities. Phonetics and pronunciation tools (28.8%): The inclusion of these tools highlights the recognition of the importance of pronunciation in reading development. Phonetics and pronunciation tools could involve creating digital stories, interactive audiobooks, or other forms of narrative content in digital format. Interactive Multimedia Resources (26%): The significant presence of interactive multimedia resources indicates an adoption of digital tools that go beyond specific applications. This could include interactive presentations, online educational games, and other resources that combine visual and auditory elements to enhance the learning experience. The preference for these technological tools suggests an adaptation to contemporary trends in education, recognizing the potential of technology to make learning to read more attractive and effective. This analysis provides valuable information to understand how technology is integrated into the context of early reading instruction. This can be seen in Fig. 3.

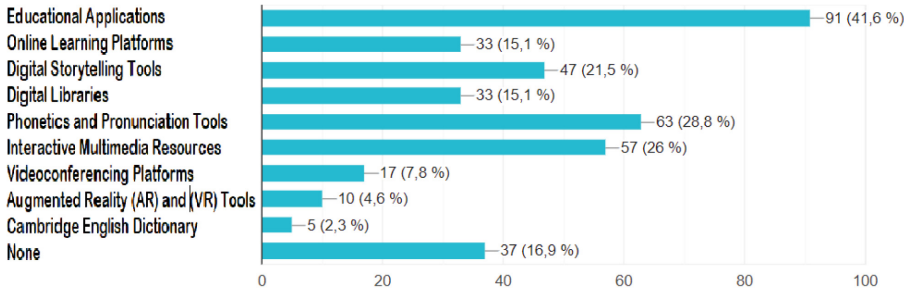

Fig. 3. Technology and Reading Do you use technological tools or multimedia resources as support for teaching reading? If so, which ones?

Analysis of data on challenges and obstacles in teaching reading at early ages reveals the following trends: Lack of Family Participation (61.6%): This result highlights the perception that the lack of family participation is the main challenge when teaching reading to children in their early years. The lack of support or involvement from families can negatively impact reading development since active parental participation is essential to strengthen reading skills at home. Variety in Skill Levels (35.2%): Recognizing the variability in skill levels among children presents a significant challenge. This diversity in students' abilities can make teaching more complex, as educators must adapt their approaches to address each child's individual needs. Developmental Differences (32.9%): Identifying developmental differences among children as a challenge underscores the importance of understanding and addressing individual disparities in the pace of reading skill acquisition. Adapting pedagogical strategies to address these differences becomes crucial. These results suggest that, from the perspective of educational professionals, family participation is essential for success in teaching reading at an early age. Additionally, variability in abilities and differences in development are challenges that

require flexible and personalized pedagogical strategies. This analysis provides valuable insight into perceived barriers, which may be useful in developing effective approaches and addressing existing challenges in teaching early reading. This can be seen in Fig. 4.

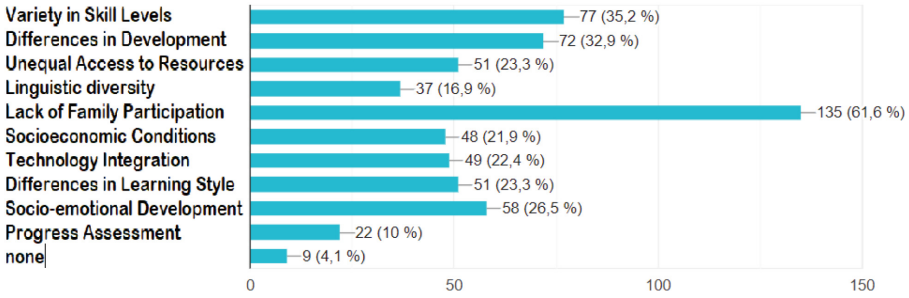

Fig. 4. Challenges and Obstacles: What do you consider to be the biggest challenges or obstacles when teaching reading at an early age?

4 Discussion

The integration of technology in education has sparked widespread discussion due to its potential to enhance teaching and learning. However, it also brings forth ethical concerns, particularly regarding student privacy and equitable access to resources. The use of digital devices and online platforms in classrooms raises questions about data privacy and exacerbates existing inequalities in access to education. Addressing these challenges requires collaborative efforts among educators, policymakers, and stakeholders to ensure ethical use of technology while promoting equity in education. Furthermore, exploring various strategies, practices, and policies can improve early reading instruction and lay solid foundations for children's academic development. Analysis of different teaching methods underscores the diverse approaches employed in early literacy education, highlighting the need for comprehensive solutions to address these issues effectively.. This discussion topic focuses on exploring the implications and benefits of each identified approach:

Game-Based Approach: How can the game-based approach improve children's participation and interest in the reading learning process?, How can this method be effectively integrated into a broader approach?, How can the phonic approach be adapted to address the individual needs of students?, Educational Applications: How can educational apps be selected and adapted to address specific aspects of learning to read, such as phonics or comprehension?

Is there evidence to support the effectiveness of certain educational applications in reading development?

Interactive Multimedia Resources: What are the key aspects of interactive multimedia resources that are most beneficial for learning to read?

Digital Storytelling Tools: To what extent do digital storytelling tools positively impact the development of reading and comprehension skills?

5 Conclusions

The study on the teaching of reading at early ages provides a comprehensive vision of the challenges, strategies, and integration of technology in this crucial process. The main findings reveal: Challenges and obstacles: Lack of family participation emerges as the most prominent challenge, highlighting the need to actively involve parents in their children's educational process. Additionally, variation in skill levels and differences in development are identified as key factors, underscoring the importance of adaptive and personalized strategies to address diverse student needs. Technology and reading: There is growing interest in the integration of technological tools in the teaching of reading, with educational applications leading the way, closely followed by interactive multimedia resources and digital storytelling tools. This reflects adaptation to contemporary trends and recognizes the potential of technology to enrich the learning experience. Reading Teaching Strategies: Diversity in methods and approaches highlights the undefrstanding that children have diverse learning styles. The game-based approach is positioned as a leader, suggesting a playful and participatory approach to teaching. The significant presence of phonetic methods reinforces the importance attributed to decoding and phonics in the development of reading. Promoting reading comprehension: Strategies to promote reading comprehension include the use of roles, open-ended questions, and manipulatives. This indicates the relevance of practical and interactive approaches to strengthen understanding and connection to content. These findings outline an integrative path where technology merges with diverse strategies, addressing challenges and promoting a holistic approach to early reading development. However, it is important to recognize the limitations of the study and additional research is recommended to evaluate the long-term effectiveness of the identified strategies and their impact in different educational contexts and student populations. Furthermore, it is suggested to explore how these strategies can be adapted and applied in non-formal and domestic environments.

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A High-Throughput FPGA-Based Elliptic Curve Digital Signature Core for IoT Edge Platforms

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Abstract. Information security is significant in many aspects, especially in IoT applications such as healthcare or monitoring. Therefore, cryptography algorithms are usually deployed on IoT edge platforms to ensure the integrity and safety of information. As one of the most attractive and efficient methods for implementing digital signature algorithms (DSA), elliptic curve cryptography (ECC) can be used for many security applications. In this work, we design and build an FPGA-based DSA hardware computing core with the ECC algorithm, called ECDSA, to accelerate the processing throughput of IoT edge platforms. We deploy the proposed system on the Kria KV260 edge computing platform with a Xilinx Zynq UltraScale+ FPGA device. Experimental results with test vectors provided by the National Institute of Standards and Technology (NIST) show that our edge computing platform can generate up to 3,361 signatures per second, with a processing throughput of up to 2.46 Mbps.

Keywords: FPGA · Hardware accelerator · ECC · ECDSA · Edge Computing · IoTs

1 Introduction

Statistics project that by 2025, people will interconnect over 75 billion IoT devices worldwide [20]. Furthermore, global spending on IoT is expected to exceed 1.1 trillion USD by 2023. As the number of IoT devices and financial investments increases, many industries are benefiting from IoT applications. In the healthcare sector [10], wearable IoT devices are increasingly utilized for patient monitoring, encompassing functionalities such as blood pressure tracking, connected inhalers, surgical robots, and intelligent hearing aids. Similarly, the smart home concept relies heavily on IoT devices for functionalities like smart door locks, lighting control, video surveillance, and home appliances [13]. Notably, the proliferation of IoT platforms geared towards smart cities has significantly increased, facilitating innovations such as intelligent streetlights, traffic management systems, and air quality monitoring solutions [5].

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Despite the widespread adoption of IoT across various industries, challenges persist due to resource limitations and energy constraints inherent in IoT devices and platforms. Additionally, there's a pressing need for enhanced security measures to mitigate risks and minimize operational expenses associated with IoT deployments. Consequently, a growing demand for integrating IoT devices with robust security solutions is increasing [11]. However, effectively accomplishing this task requires addressing the inherent limitations of IoT ecosystems' hardware, networking, and software components.

In recent years, to overcome the limitations in terms of hardware components and processing performance, FPGA-based computing platforms have been exploited for IoT edge computing [4]. However, in terms of data security and protection, there are not many studies in the literature integrating digital signature algorithms to FPGA-based IoT computing platforms for protecting data integrity, confidentiality, and authentication. Therefore, this paper introduces our design and implementation of an ECC-based digital signature algorithm (ECDSA) for FPGA-based edge computing. The proposed system can increase data security levels and processing throughput and performance due to the high parallelism of FPGA devices. We build the proposed system on the Xilinx Kria KV260 edge computing platform as our prototype and test with a dataset provided by NIST [14]. The experimental results show that our platform outperforms state-of-the-art implementation regarding throughput for EDCSA. Our system can offer up to 3,361 signatures per second with a throughput of 2.46 Mbps.

The main contributions of our paper can be summarized in three folds.

1. We introduced our efficient FPGA-based ECC digital signature hardware core for accelerating the processing performance of IoT platforms.
2. We illustrate our proposed system with the prototype on Xilinx Kria KV260 edge computing platform to evaluate performance and throughput.
3. We analyze our experimental results based on the prototype platform and dataset provided by NIST to reference other future studies.

The rest of the paper is organized as follows. Section 2 shows the preliminaries of ECDSA and related work. We introduce our proposed FPGA-based ECDSA core in Sect. 3. Section 4 depicts our prototype with Xilinx Kria KV260 edge computing. Experiments with dataset provided by NIST and the prototype platform are analyzed in Sect. 5. Finally, Sect. 6 concludes our paper.

2 Preliminaries and Related Work

In this section, we first present the background of digital signature in data security and the elliptic curve digital signature algorithm (ECDSA). We then analyzed related work in the literature targeting ECDSA on FPGA devices.

2.1 Digital Signature for Data Security

The Digital Signature Algorithm (DSA) is a widely used cryptographic algorithm that facilitates the creation and verification of digital signatures. DSA offers several critical advantages for digital signature applications, such as: (i) Security: DSA relies on mathematical properties that make it computationally infeasible to forge signatures without knowing the signer's private key. (ii) Non-repudiation: Once a signature is created, the signer cannot deny signing the message, providing a solid form of non-repudiation. (iii) Efficiency: DSA offers relatively fast signing and verification processes, making it suitable for real-time applications. DSA was approved as a digital signature standard (DSS) by NIST in 1994, and it includes four primary steps [6].

1. **Key generation**: The process begins with key generation. The signer generates a pair of cryptographic keys-a private key and a corresponding public key. The private key is kept confidential and used by the signer to create digital signatures, while the public key is shared with others for signature verification.
2. **Message hashing**: Before signing a message, the signer typically calculates a cryptographic hash of the message using a secure hashing algorithm such as SHA-256. This hash serves as a unique message representation and ensures message integrity.
3. **Signing**: The signer generates a digital signature for the message using their private key. This involves applying mathematical operations to the message hash and the private key to produce the signature, which is specific to both the message and the signer's private key.
4. **Verification**: Upon receiving the message and its associated signature, the recipient can verify the authenticity and integrity of the message. The recipient uses the sender's public key to verify the signature. This process involves applying mathematical operations to the message, the signature, and the sender's public key to determine whether the signature is valid. If the verification process succeeds, the recipient can be confident that the claimed sender indeed sent the message and that it has not been altered since it was signed.

2.2 Elliptic Curve Digital Signature Algorithm

ECDSA, approved by NIST in 2000, is a variant of DSA based on elliptic curve cryptography (ECC) for generating private and public keys. Like the original DSA, ECDSA includes four steps: key generation, hash, signing, and verification. During the key generation step, a base point on the curve is chosen to generate private and public keys based on this point. SHA-256 hash function is usually used to hash the plaintext before signing. In the signing step, the signature (r, s) value will be generated based on the point of the curve, the private key, and the hash message. Finally, the receiver will use the public key to validate the signature attached to the received message. Figure 1 depicts the generic DSA and also illustrates the ECDSA variant.

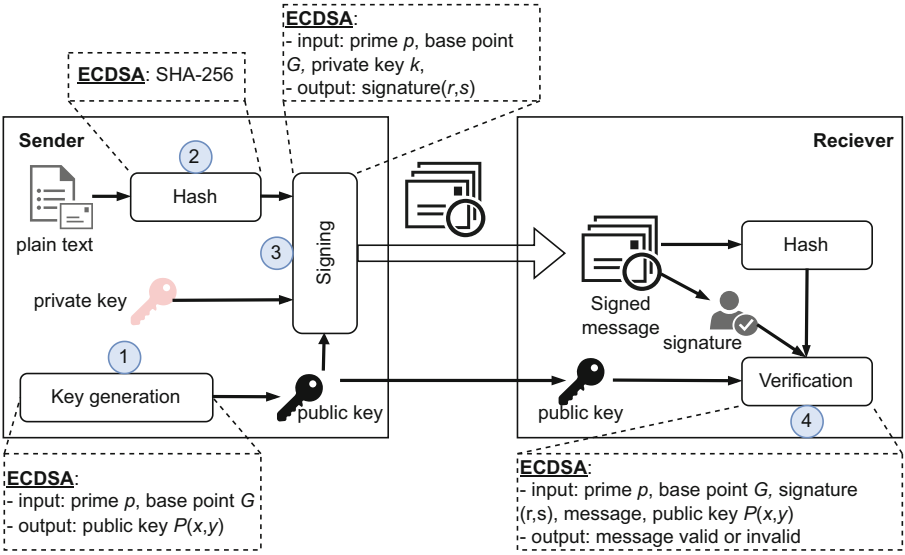

Fig. 1. The general Digital Signature Algorithm and the Elliptic Curve Digital Signature instance

2.3 Related Work

In recent years, many authors have proposed FPGA-based ECDSA systems in the literature. Benjamin Glas introduced a prime field ECDSA signature generating on FPGA [9]. The system is deployed on a Virtex 5 FPGA board that offers up to 138 signatures per second (7.257 ms latency) with the secp256k1 elliptic curve. Elhadjyoussef Wajih targets the low power goal of designing an ECDSA system with a 163-bit elliptic curve [21]. Virtex 4 FPGA devices are used to test the system, which offers a 0.609 ms latency for signing. A Low-resource 32-bit Datapath ECDSA was introduced in [22] that offers 1.58 ms latency for signature generation. The proposed approach targets both ASIC and FPGA technology with experiments on Virtex 5 devices. The testing system uses a 163-bit elliptic curve. Anissa Sghaier designed and implemented an ECC-based DSA hardware core on Virtex 5 FPGA, targeting the low power and area goals [19]. The core used the 163-bit elliptic curve instead of 256-bit in our work. Experimental results show that the system can produce a signature in 1.5ms with a throughput of 0.16 Mbps. A reconfigurable ECDSA FPGA-based core for accelerating a soft processor is proposed in [15]. The proposed core can process the elliptic curve from 192 to 521 bits with Virtex 6 devices and produce signatures after 9.145 ms and 11.92 ms, respectively. An FPGA-based high-speed and area-efficient EDCSA processor was presented in [12]. In this work, a 256-bit elliptic curve and Virtex 7 FPGA device are used to test the processor. The proposed processor can provide 173 kbps throughput with 1.48 ms latency for generating a signature. Binh introduced a DSA engine with both an elliptic curve and an

Edward curve with different sizes of curves (256, 384, 512 bits) [8]. The proposed engine is built with Xilinx Virtex 7 FPGA targeting area constraints. The system requires 15.86 ms for the key generation and signing process with SHA-256.

Compared to these proposals, we target edge computing platforms instead of general-purpose systems. In terms of throughput (signatures per second), we outperform these proposals when testing with the dataset provided by NIST.

3 Proposed ECDSA Hardware Architecture

In this section, we introduce our FPGA-based ECDSA computing core. We design the core according to the hardware accelerator paradigm [17] so that the core can be integrated with different hardwired or soft general-purpose processors to develop applications.

3.1 Overview Architecture

Figure 2 illustrates the overview architecture of our ECDSA core. The core communicates with the host processor through a bus interface for transferring input data (parameters, messages, prime number,...) and output results (signed message, public key,...). Exchange registers and a buffer are used for this purpose.

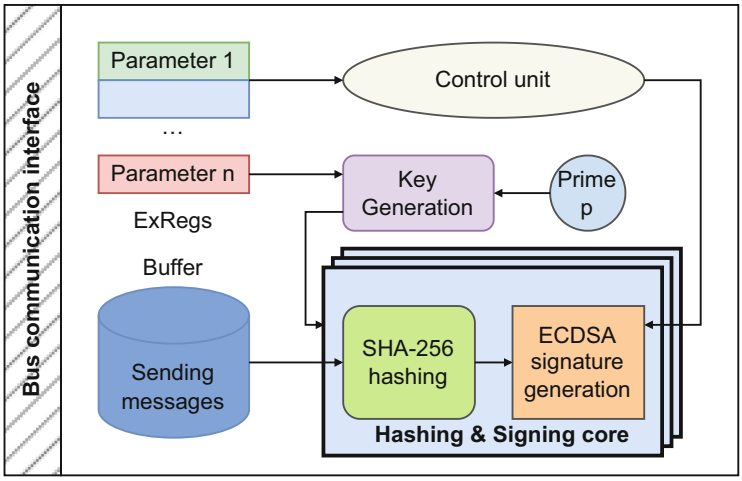

Fig. 2. The overview of the ECDSA hardware core

The main component in this module is the Hashing & Signing core for conducting the hashing and signing steps of the ECDSA process (the second and the third steps). To improve the performance, we implement multiple `Hashing`

`& Signing` cores based on the available resources of the FPGA platforms since this is a time-consuming step. Each core sequentially receives a message from the buffer and conducts SHA-256 hashing before generating the signature according to the ECC algorithm. This work uses SHA-256 to improve security against attacks instead of SHA-1 in proposals presented in Sect. 2.3. To implement the SHA-256 hardware module, we build a hashing table and replace the text of original messages with hashing values. We have yet to show this implementation because this is trivial work and due to space limitations.

3.2 ECDSA Signature Generation

This section presents the details of the ECDSA signature generation sub-module. According to the ECDSA process's operations hierarchy, the signature generation sub-module ultimately requires addition/subtraction modular and multiplication modular operations [7]. Therefore, we present our proposed efficient modular addition/subtraction and modular multiplier architectures as shown in Fig. 3 and Fig. 4, respectively.

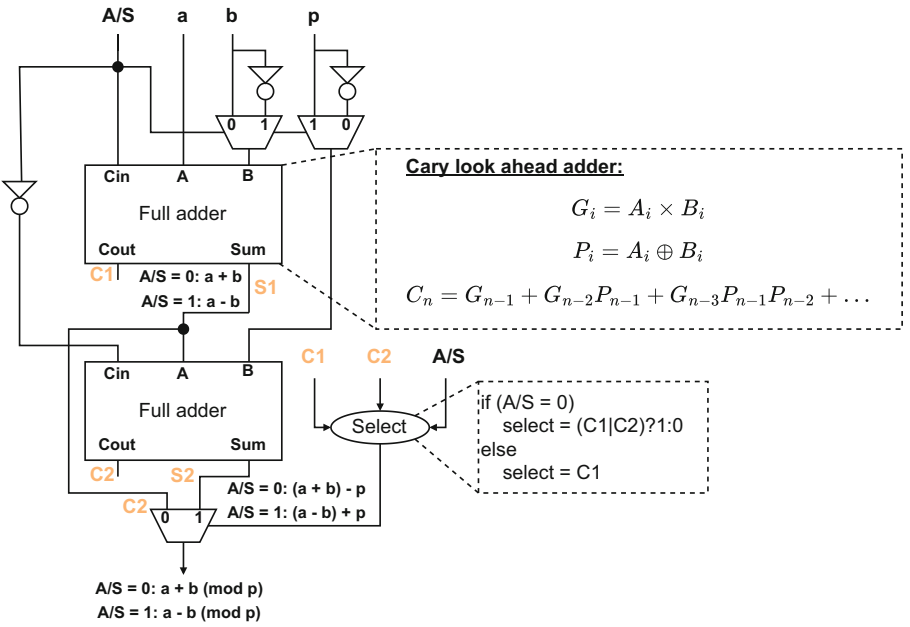

Fig. 3. The modular addition and subtraction

Modular addition and subtraction are the leading operators in the signature generation process. The two operators add or subtract two values a and b before applying the modulo with a selected prime number p to produce $a + b(\text{mod } p)$ or $a - b(\text{mod } p)$ $(a, b \in [0, p-1])$. Figure 3 presents our hardware architecture for computing these operators based on the algorithms presented in [1]. The `A/S` signal allows the core to select modular addition or subtraction.

To calculate modular addition $a+b(\text{mod } p)$, the `A/S` is set to 0 for adding two numbers a and b at the first round. We build our `Full-adder` modules with the carry look-ahead approach to save processing time. The sum of the first adder $S1$ is then added with 2's complement of p for performing $S1 - p$. Finally, the `Select` block selects the final results based on carry-out values `C1` and `C2`. If any carry-out value is 1, then the `S2` output of the second `Full-adder` is the final result; otherwise, selecting the `S1` output of the first `Full-adder`. When `A/S` is set to 1, the core computes modular subtraction $a - b(\text{mod } p)$. Like the modular addition, the first `Full-adder` subtracts b from a by applying 2's complement addition operator. Then, the second `Full-adder` adds the result of the first one with p. The final result is selected based on the value of carry-out bit C1.

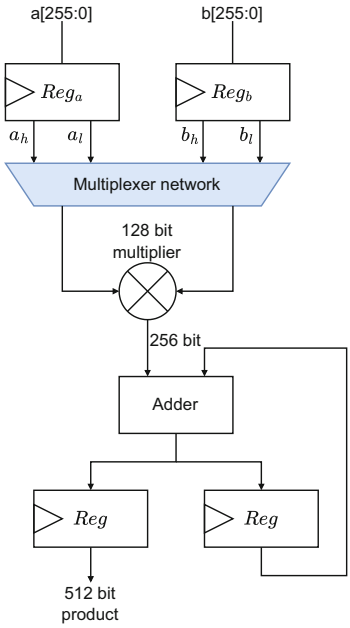

Fig. 4. The modular multiplication

Along with the modular addition and subtraction operators, ECDSA requires many modular multiplication operations. The hardware architecture shown in Fig. 4 represents our pipeline multiplication core. As the SHA-256 and 256-bit

elliptic curves are used for hashing and signature generation, 256-bit multiplication is required. We use the pipeline approach to save computing time by dividing the numbers into high-halves (a_h&b_h) and low-halves (a_l&b_l). These numbers are multiplied and added through a multiplexer network, a 128-bit multiplier, and adders.

4 FPGA Edge Computing Prototype

This section presents our prototype FPGA-based edge computing platform with an integrated ECDSA core. In this work, we use the Xilinx Kria KV260 edge computing system [2] to deploy our prototype. The platform contains a Xilinx Zynq UltraScale+ MPSoC ZU5CG with 256K logic cells, 144 Block RAM (36 Kbits/block), and other components. With this amount of resources, we can build an ECDSA core with two `Hashing and Signing cores`, i.e., two separate messages can be hashed and signed in parallel. Modules for the core are described by Verilog HDL and synthesized with Xilinx Vivado [3]. Along with the reconfigurable logic for building the ECDSA core, the Zynq FPGA chip also contains a hardwired Dual-core ARM Cortex-A53 processor for executing software.

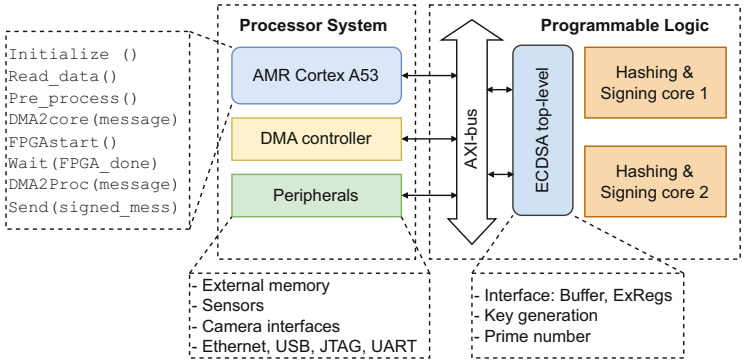

Fig. 5. The prototype system with Xilinx Kria KV260 board

Figure 5 presents the overview of our prototype system. In this prototype, the hardwired ARM processor is a host processor for controlling and collecting data from peripherals like sensors and cameras and communicating with the cloud through the Ethernet interface. Before sending a message to the cloud/server, the host processor starts transferring data to our ECDSA core by Direct Memory Access (DMA) through the AXI bus interface for the signing process. During this interval, the host processor can wait or perform other tasks-the signed messages after that are transferred back from the ECDSA core for sending to the cloud.

5 Experiments

This section presents our experiments for testing and evaluating our ECDSA core and the prototype system. We mainly focus on the signing process's performance; hence, we compare our core with related work in terms of performance and processing throughput.

5.1 Experimental Setup

For testing and validating the proposed ECDSA core, Xilinx Vivado is used for simulating. The prototype system with the validated ECDSA core is then synthesized to the Xilinx Kria KV260 board. The test vector provided by NIST [14] is applied to the simulation and actual system testing process. Figure 6 illustrates a testcase with simulation using the NIST test vector.

```
private=c5c20cf07687e946628012{217447efcd89783594e3be3ffb9bca1deb00420d3,
message=f9643cb57a24131fb061601c7ce0e5a2254ceebd7f737b7f126dcbdb5ce8aea0e2a112a6c0b9fb3f5dfdc1a154bc0c43518481
e70fe8e57c2a5b463c7ac46f45
signature=xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
private=c5c20cf07687e946628012f217447efcd89783594e3be3ffb9bca1deb00420d3
message=f9643cb57a24131fb061601c7ce0e5a2254ceebd7f737b7f126dcbdb5ce8aea0e2a112a6c0b9fb3f5dfdc1a154bc0c43518481
e70fe8e57c2a5b463c7ac46f45
signature=1df1294e2cc2982422011fe6c10dceb5e20e1ce379652a2332b86066aed53c17232d8aa5b07724a117b294aa7fb57e73ab4b
56a16662b600ae81a9cc5b5bb499
run: Time (s): cpu = 00:00:04 ; elapsed = 00:00:07 . Memory (MB): peak = 1753.125 ; gain = 0.000
```

Fig. 6. Simulation result of a message from NIST

A computer connected to the board through the SSH connection functions as a cloud server to receive signed messages for comparison with results provided by NIST. This computer is also used to measure the elapsed time that the system needs for the entire signing process (including data communication overhead between the host processor and cores). The elapsed time is used to compare the performance of the proposed system with related work in the literature and calculate throughput in terms of signatures per second. Figure 7 shows a testing case with the test vector provided by NIST.

```
ubuntu@kria:~/server/file$ source run.sh
remove from slot 0 returns: 0 (Ok)
bram_wrapper: loaded to slot 0
Message: f9 64 3c b5 7a 24 13 1f b0 61 60 1c 7c e1 e5 a2 25 4c ee bd 7f 73 7b 7f 12 6d cb db 5c e8 ae a1 e2 a1
12 a6 c0 b9 fb 3f 5d fd c1 a1 54 bc 0c 43 51 84 81
Private key:c5 c2 0c f0 76 87 e9 46 62 80 12 f2 17 44 7e fc d8 97 83 59 4e 3b e3 ff b9 bc a1 de b0 04 20 d3
Signature: 1d f1 29 4e 2c c2 98 24 22 01 1f e6 c1 0d ce b5 e2 0e 1c e3 79 65 2a 23 32 b8 60 66 ae d5 3c 17 23
2d 8a a5 b0 77 24 a1 17 b2 94 aa 7f b5 7e 73 ab 4b
Compare with expected value: PASS
Latency: 0.597298 ms
```

Fig. 7. Testing result of a message from NIST on Kria KV260

To analyze the hardware resource usage, working frequency, and power consumption, we extract data from the synthesis report generated by Vivado. Based on the latency for processing messages, we compute processing throughput and compare it with other work.

5.2 Synthesis Results

The ECDSA core, developed by Verilog-HDL, and the entire system are synthesized and configured on the Kria board by Xilinx Vivado 2023.2. Synthesis report shows that with two `Hashing & Signing` cores, the system can work at 106.2 MHz and requires 3.1 W total power consumption. Table 1 details hardware resource usage for the system when the system is deployed with one and two `Hashing & Signing` cores.

Table 1. Hardware resources usage for the proposed system with one or two `Hashing & Signing` cores

Resources	2 cores		1 core		Available
	Amount	Percentage	Amount	Percentage	
Look-up tables (LUTs)	60,389	51.56%	32,186	27,48%	117,120
Flip-flop (FFs)	28,932	12,35%	16,557	7.07%	234,240
DSP	66	5.28%	50	4.01%	1,248
Block RAMs (BRAMs)	4	0.85%	4	0.85%	352

As shown in the table, our system uses up to 51,56% hardware resources of the FPGA device, i.e., we can integrate more cores to improve the performance of the computing platform further. With the hardware accelerator computing paradigm, the system also allows us to incorporate other cores for particular purposes, such as video encoder/decoder [16] or attack detection [18] to improve processing ability and overall performance of the IoT edge computing platform.

5.3 Performance Evaluation and Comparison

In this section, we thoroughly evaluate the performance of our system, focusing on three critical metrics: latency for generating a signature, throughput in signatures per second, and throughput in bits per second. Our evaluation is grounded in a comprehensive dataset sourced from NIST, which forms the basis for our rigorous testing procedures. This dataset comprises numerous test cases, each meticulously crafted to contain 64 bytes of data alongside a 32-byte private key. Through careful experimentation and analysis, we aim to provide a detailed understanding of our system's capabilities and limitations across various scenarios. The results of our evaluations, shown in Table 2, shed light on the performance and throughput of our system, particularly when utilizing two `Hashing and Signing` cores. These insights are a foundation for optimizing system design and enhancing overall performance in real-world applications.

Table 2. Performance comparison

Proposal	Device	Elliptic (bits)	Latency (ms)	Signatures/s	Throughput
[9]	Virtex 5	256	7.257	138	N/A
[21]	Virtex 4	163	0.609	1,642	NA
[22]	Virtex 5	163	1.58	633	173 Kbps
[19]	Virtex 5	163	1.5	667	0.16 Mbps
[15]	Virtex 6	192	9.145	109	N/A
		521	11.92	84	
[12]	Virtex 7	256	1.48	676	NA
[8](1)	Virtex 7	256	19.8	202	N/A
		384	44.44	90	
		512	83,34	48	
Ours(2)	**Zynq**	**256**	**0.595**	**3,361**	**2.46 Mbps**

(1)The work in [8] built 4 ECDSA cores. (2) Our work also built two ECDSA cores.

As illustrated in the table, our system demonstrates remarkable efficiency, boasting the most negligible latency in signature generation compared to existing methodologies. Notably, our performance surpasses even proposals employing the 163-bit Elliptic curve, underscoring the robustness and effectiveness of our approach. Moreover, in terms of signatures per second, the utilization of dual `Hashing & Signing` cores offers a significant advantage, propelling us to achieve 2× the throughput of the following best system in this comparative analysis. This superior performance highlights the efficacy of our system architecture and reinforces its viability for demanding real-world applications where speed and efficiency are paramount concerns.

6 Conclusion

Security is paramount in various domains, particularly in Internet of Things (IoT) applications like healthcare and monitoring. Hence, cryptographic algorithms are commonly utilized on IoT edge platforms to safeguard the integrity and confidentiality of data. Elliptic curve cryptography (ECC) stands out as an appealing and efficient approach for implementing digital signature algorithms (DSA), suitable for numerous security applications. In this study, we propose the development of an FPGA-based DSA hardware computing core featuring the ECC algorithm, known as ECDSA, aimed at enhancing the processing throughput of IoT edge platforms. Thanks to the massive hardware resources of FPGA devices, multicore architecture has been applied to further improved the system throughput. Our system is deployed on the Kria KV260 edge computing platform equipped with a Xilinx Zynq UltraScale+ FPGA device. Evaluation using test vectors provided by the National Institute of Standards and Technology (NIST)

demonstrates that our edge computing platform can achieve a signature generation rate of up to 3,361 signatures per second, with a processing throughput reaching up to 2.46 Mbps.

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Internet of Things for Plastic Bottle Recycling: A Case Study for Salinas

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Abstract. Waste generation is growing worldwide because of urbanization and population growth. Plastic bottles are being discarded incorrectly polluting the environment and wasting resources. Reverse vending machines that work with the Internet of Things offer a great possibility to promote plastic bottle recycling at locations where recycling is not compulsory. For the first phase, the current plastic bottle waste management system was determined for the municipality of Salinas using a literature review, interviews, and field visits. An improved model was suggested to address the main concerns and promote plastic recycling among other materials. An important part of the model is reverse vending machines for plastic bottles. Phase two relates to the design of the reverse vending machine. The researchers performed a literature review to determine the features of different reverse vending machines with IoT technology. A process flow chart was elaborated to establish the different systems for the machine. Once the characteristics of the machine were determined it was drawn using Autocad 3D. The machine designed detects, collects, compresses, and storages empty plastic bottles up to 1 L. The electronic circuit includes the Internet of Things technology to award economic compensation for recycling and alert when the storage bin needs to be emptied to avoid overload, using Wi-Fi communication. These machines should be implemented in central locations like supermarkets, restaurants, and schools around the municipality of Salinas and evaluated for other municipalities of the province of Santa Elena and Ecuador.

Keywords: Waste management · Internet of Things · bottle compacting · recycling · reverse vending machine

1 Introduction

Waste is rising because of urbanization and population growth worldwide [1]. The World Bank estimated that waste generation will reach 2.59 billion tons by 2030. In some developing countries, waste disposal is not correctly performed as landfills are unavailable, which can be health and environmental hazards [2]. Plastic production has continuously increased since the 1950s, and its global annual generation reached 330 million metric tons in 2016 [3]. Plastic accounted for 12 percent of global waste [2].

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Plastics are a fundamental part of society; however, their incorrect disposal may raise concerns as human and animal health can be affected. As most petroleum-based plastics are non-biodegradable, plastic waste has become a threat to the environment. Plastic pollution is spread worldwide and can produce climate destabilization. Plastics are accumulated across the environment along many landscapes. Around 400 million tons of plastic are produced for different applications [4]. Plastics discarded on land may reach oceans downstream. Around 14 million tons of plastic waste go to the ocean. Plastics can harm animals or be eaten by them. These plastics unproperly managed can endanger food security, diminish food quality, affect animal and human health, affect tourism, and contribute to climate change [5].

The main problem of plastic pollution is the current linear economy which involves single use of plastics before final disposal. There must be a shift to a circular economy where plastics are driven to new uses. Recycling transforms waste into new materials allowing us to save raw materials and reduce energy consumption and greenhouse emissions. Advances in manufacturing processes have increased the percentage of recycled plastic; however, it remains small even in Europe which has strong policies to protect the environment [6]. Discarded plastic bottles pose a threat to the environment as consumption of bottled drinks has kept growing in the last decade [7].

Even though there have been important investments in the recycling industry, plastic recycling faces barriers such as the complexity of identifying which plastics are recyclable, not prioritizing recycling, and believing that plastic recycling is complex [8]. Policies to reduce the plastic problem include an upstream approach as reducing and replacing and a downstream approach as collecting, reusing, and recycling [9]. In addition to the downstream approach, reverse vending machines have been implemented worldwide to ease and increase waste collection.

To manage population growth, rapid urbanization, and lifestyle changes, it is necessary to develop smart sustainable cities. A fundamental pillar of green smart cities is waste management [10]. Municipalities in developing and developed countries have the challenge of implementing efficient waste management systems to collect, transport, recycle, and dispose of waste by health and environmental standards. Efficient waste collection may be hindered by problems with bin collection, overloaded bins, inefficient picking routes, limited resources, and other aspects [11].

Smart cities are urban zones that use information and communication technologies with sensors, and interconnected devices to generate information that is analyzed to improve operational efficiency, public transportation, daily activities, and life quality [10–12]. A smart city is environmentally friendly, socially inclusive, and sustainable [13]. Technology with data analytics will reshape lives when citizens access personalized and improved aspects like economy, mobility, governance, and awareness [14]. Important features of a smart city are environmental conservation and citizens' health which can be achieved by implementing an adequate smart waste management system [13]. Smart cities rely on the Internet of Things (IoT) technology to provide the feature of smartness to different services.

The Internet of Things relates to a network of interconnected objects that incorporate sensors, software, and technology to communicate with each other and with the cloud. People, things, and processes are connected anywhere and anytime to reshape existing services and create innovative ones in the context of smart cities [12]. The IoT technology is currently used to improve waste management worldwide and has continuously been studied to create new solutions related to waste [15]. IoT has been studied to create dynamic routing and scheduling of garbage trucks, smart waste bins, waste segregation, recycling, waste reduction, waste disposal, and environmental monitoring and for decision-making [16].

In the waste segregation field, waste bins have been equipped with sensors, IoT technology, and in some cases, computer vision and machine learning to distinguish the different materials waste is made of and classify them into different categories [17, 18]. The IoT technology has been implemented in reverse-vending machines to aid waste segregation and further recycling.

Vending machines are machines that give merchandise automatically in exchange for money. Reverse vending machines work oppositely by receiving used containers and returning rewards or monetary benefits [19]. These devices have different systems which include container deposit, material recognition, compaction (in some cases), storage, and incentives [20]. Reverse-vending machines can be an effective way of collecting plastic waste for recycling in exchange for incentives or money [21]. In countries where recycling is compulsory, reverse vending machines collect around 70% of beverage containers [22]. Reverse vending machine technology is migrating from old-time systems to digital systems that use IoT technology and return rewards related to the weight processed [23].

While reverse vending machines have been widely used in some parts of the world, in some countries, where recycling is not mandatory, they are barely used. In Ecuador, reverse vending machines have been studied in bachelor's thesis for Quito [24, 25] and Riobamba [26, 27]. In the municipality of Salinas, reverse vending machines have not been investigated before; therefore, it is necessary to study this type of machine which works with the IoT technology to promote the collection of plastic bottles for recycling.

2 Materials and Methods

2.1 Study Area

The study area is the municipality of Salinas, located in the province of Santa Elena of Ecuador. Santa Elena Province has three municipalities, Santa Elena, Salinas, and La Libertad. The main productive activities include fishery, aquaculture, tourism, and agriculture, among others [28, 29]. For the year 2022, Ecuador had almost 17 million inhabitants and Salinas municipality has 86 801 inhabitants in 37 490 dwellings. Salinas is located on the coast of the Santa Elena Peninsula [30] (see Fig. 1).



Fig. 1. Location of Salinas [31]

2.2 Methodology

This methodology describes the two phases performed for this study (see Fig. 2). Phase one intends to establish the current plastic bottle waste management model. A literature review was performed to establish the different elements a waste management system has and gather information about the current practices of waste management at the Municipality of Salinas. Interviews and field visits were performed to determine the streams plastic bottles follow. Municipal workers, private workers, formal recyclers, and informal recyclers were approached with semi-structured interviews. Field visits were performed to plastic bottle collection sites. Once the current model was established, an improved model was created using recommendations gathered during interviews and concepts of circular economy considering the current local situation. This study analyzed plastic bottles discarded in the city of Salinas and did not extend to rural areas. Few informal recyclers were approached because of high crime rates (study limitations).

Phase two relates to the design of the plastic bottle reverse vending machine for Santa Elena province. The researchers performed a literature review to determine the features of different reverse vending machines with IoT technology that have been implemented and studied before. A list and a process flow chart were elaborated to establish the different systems the machine will use. It was necessary to define a compaction method to establish the different elements of the machine. This study was limited to plastic bottles up to 1 L. The machine capacity was determined by comparing the capacity of machines designed for other provinces of Ecuador and their inhabitants. The elements of the electronic circuit of the machine were selected to comply with the requirements established for the machine. Once the characteristics of the machine were determined it was drawn using Autocad 3D. Economic feasibility was determined under the considerations of national law for plastic bottle recycling and according to the machine design capacity.

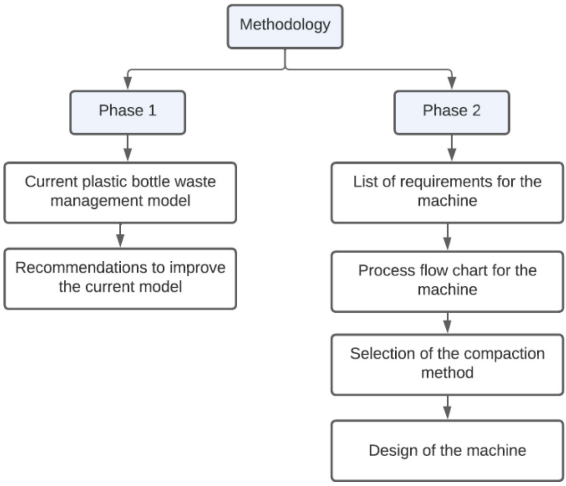

Fig. 2. Methodology

3 Results and Discussion

First, the current plastic bottle waste management model was determined for Salinas Municipality (see Fig. 3). The municipality operates as final disposal an open dump site. This practice poses a threat to the environment and health. Waste collection and disposal is a service offered by the municipality which is charged to citizens in electricity bills. The current waste collection is performed by waste trucks which pick up garbage bags. Bins or differentiated collection is not compulsory and has not yet been implemented by the municipality of Salinas. However, this does not imply that all plastic bottles are not collected for recycling. Formal and informal recyclers collect recyclables which include plastic bottles by opening plastic bags. Formal recyclers are pickers who are part of associations legally established. In addition, some citizens place recyclables in different bags or aside from normal waste bags to ease the collection of them. In some cases, recyclers even purchase recyclables from houses and institutions. Most recyclers drive load tricycles; however, there are also pickups and trucks. Another method that has been implemented, is drop-off recycling. Large bins have been installed at some central locations like supermarkets, schools, restaurants, and beaches, however, users do not receive any kind of compensation for taking waste to these containers. All the plastic bottles collected are transported by truck to Guayaquil City (which is in another province) where they are sold to recycling facilities. Despite the efforts made by recyclers, there remain plastic bottles inside waste bags that are collected by waste trucks and sent to final disposal in the municipality dump site. Other plastic bottles end up polluting the beaches around the province. There are some groups of young people who perform campaigns to collect waste from beaches; however, there are still some plastic bottles that remain on beaches and in the ocean. The amount of waste generated from plastic bottles and the amount of each stream has not been determined. Salinas faces specific challenges regarding plastic collection as it is one of the few municipalities in the country that does not report the weight of recyclable materials collected as equipment for this purpose has

not been implemented at the dumping sites. As tourism is a main productive activity for the county, an important number of plastic bottles is generated during holidays.

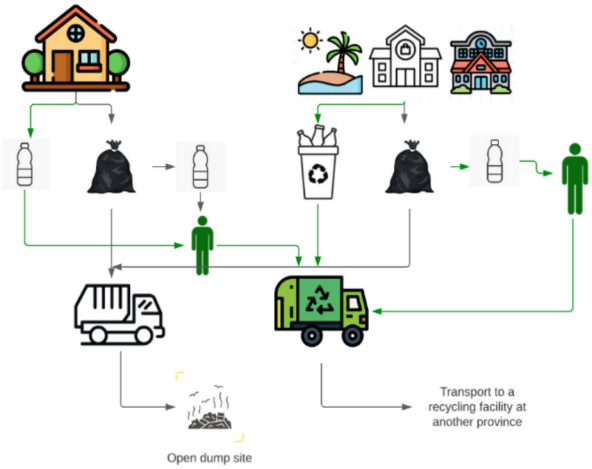

Fig. 3. Current plastic bottle waste management system

Figure 4 summarizes an improved waste management system for any municipality of Santa Elena province. A major concern of the current waste management is the open dump sites; therefore, it is suggested to build a landfill. A study performed in 2023 [32], established the approximate cost and the feasibility of a landfill for Santa Elena province as it is compulsory for municipalities to close technically open dump sites and build landfills. Waste bags should be replaced by containers and special waste trucks for containers acquired. It should be analyzed if filling level sensors should be installed in the bins [33]. Other municipalities in Ecuador, like Riobamba, Ambato, and Cuenca have in place waste containers for more than a decade, showing it is feasible to implement this technology in the country. There is the opportunity to implement initiatives related to smart cities like smart bins, smart waste trucks, and efficient collecting routes created through machine learning. Curbside bins for recyclables should be placed and more bins for collecting recyclables should be installed in supermarkets, schools, churches, restaurants, and other central locations. Recyclers would no longer be able to collect the same quantity of recyclable materials as with the previous model, however, some of these people could be employed in the transfer station where recyclables will be separated. Awareness campaigns should be performed by municipalities to introduce the appropriate use of bins for recyclables to citizens. Incentives should be considered to motivate waste segregation. Regarding incentives, this study proposes implementing reverse vending machines for plastic bottles with IoT in central locations that will be explained in detail.

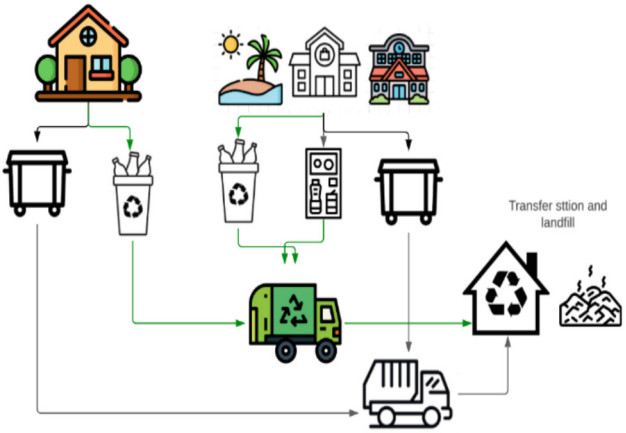

Fig. 4. Proposed waste management system

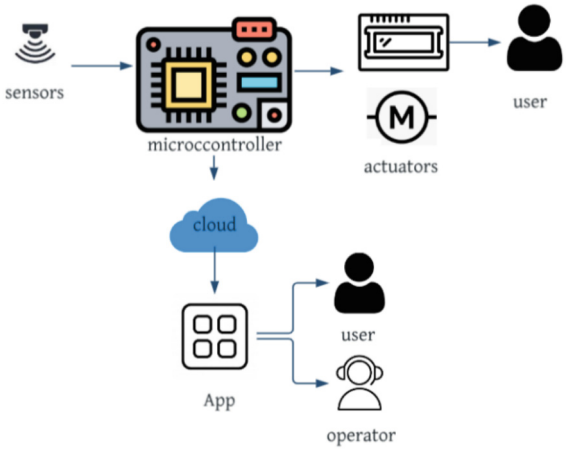

Fig. 5. Proposed IoT layers

The IoT infrastructure is organized into three layers. On the first one, sensors are located (see Fig. 5), they gather information like a rejection of an item, the weight of an accepted bottle, storage filling level, and data of bottles to be redeemed according to the identification number. This layer also includes actuators like servo motors and the LCD. Sensors and actuators have wired communication with the chip microcontroller ESP32. The next layer is the communication layer. The gathered information is transferred through this layer using the Wi-Fi technology to the cloud so it can be processed and analyzed. The machine requires an electric supply and as it is designed to be installed in central locations, electricity and Wi-Fi are available in this kind of location. The last layer is the processing and application layer. An application alerts the operator when the bin is 80%, 90%, and full so it can be emptied on time to prevent the machine to not being able to process more plastic bottles. The central system processes the received

data of weights according to each identification number to update users' balance so it can later be redeemed. This layer involves backend processing and cloud computing.

The machine can process empty plastic bottles up to 1000 ml and has a storage capacity of 500 compressed bottles. Its dimensions are $80 \times 80 \times 180$ cm. The user places an empty plastic bottle into the entry compartment which has a rounded shape to prevent big objects from being introduced into the machine (see Fig. 6). The keypad is located next to the entry compartment. The door to remove the rejected items is placed down the handle to open and empty the bin.



Fig. 6. Proposed reverse vending machine

The proximity infrared reflective sensor TCRT5000 detects if the item is made of plastic (see Figs. 7 and 8). If not, it is rejected, sent back to the user and a message is shown on the LCD. When an inserted item needs to be rejected a step servomotor 1 is activated and rotates 90° so the item can fall into a canal where the user can pick it up, later the motor returns to its original position. At the entry, a load scale (capacity of 5 kg) helps to determine if the item needs to be returned because it is not empty or is not a plastic bottle. After the bottle is accepted, the LCD shows a message asking the user to introduce his identification number so his bottles can be redeemed. Each bottle accounts for 2 American cents, in compliance with an Ecuadorian law for plastic bottles. After the bottle is accepted, servomotor number two activates a linear conveyor until the bottle reaches a normally closed limit switch sensor at the beginning of the compression system. This system is operated by a 0.5 HP alternating current motor which is coupled to grooved rollers. The rollers are grooved so the air that is inside the bottle can escape. The compressed bottle goes to the storage compartment where the ultrasound distance sensor HC-S0R04 senses the filling level alerting the operator when the bin is 80%, 90%, and 100% full.

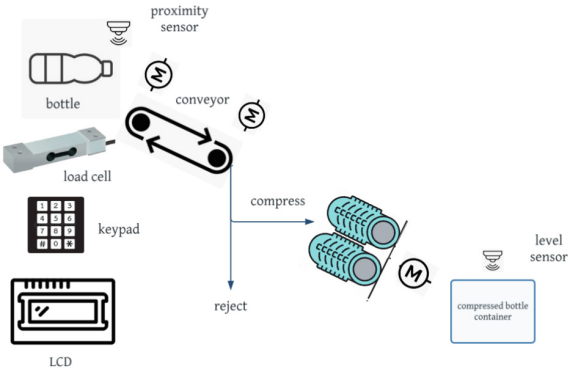

Fig. 7. Components scheme of the proposed reverse vending machine

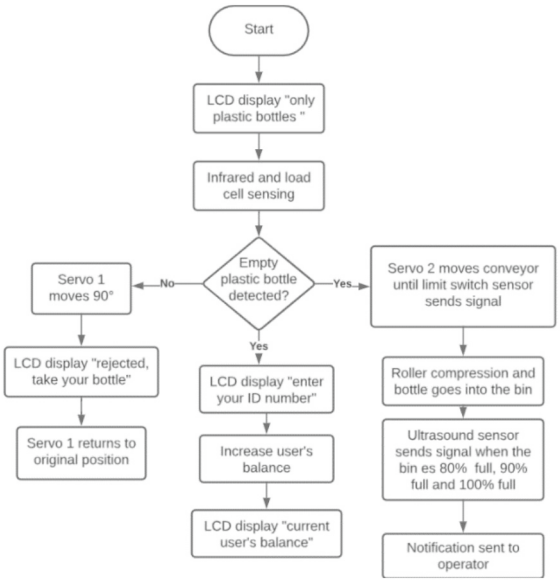

Fig. 8. Flow diagram for the reverse vending machine

The economic feasibility considered a capacity of 1000 bottles per day. The initial investment for setting up the RVMs amounts to $1,500. The investment is projected to be recovered by the fifth year of operation. Calculations yield an NPV of $1,200, indicating positive profitability. The calculations adhere to Ecuadorian legislation, which sets a bottle sale price of 2 cents per bottle. Long-term maintenance and operational costs were considered.

4 Conclusions

The current plastic waste management system of the three municipalities of the province was studied and detected that although plastic bottles are being collected by recyclers, this activity could be improved using reverse vending machines at central locations like supermarkets, restaurants, and schools. A model of a plastic bottle reverse machine which includes IoT technology was proposed. The IoT is used to allocate the economic compensation for recycling and alerting when the bin needs to be emptied. To increase the machine capacity, rollers compress the bottles. Users introduce their identification number so two cents per bottle can be later redeemed. The technical and economic feasibility are positive under Ecuadorian law considerations. The implementation of reverse vending machines should be performed in the province of Santa Elena with campaigns to raise awareness of the importance of recycling. Further research should include image recognition, and machine learning algorithms to improve rejected items detection.

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Disclosure of Interests. The author(s) have no conflict of interest to declare.

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Evaluation of a Fintech Sales Synthetic Data Generation Model Using a Generative Adversarial Network

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Abstract. The need for more and better information for decision making is fundamental in modern organizations, especially in the financial industry. One type of this information is time series, which allow prediction and estimation of different scenarios, but are difficult to obtain for small and medium sized enterprises (SMEs). This research presents the design and validation of a generative adversarial network (GAN) capable of generating synthetic data for daily sales of Chilean SME. The problem that needs to be resolved is the lack of this kind of data within a Chilean fintech company called Dank. This data can be useful in developing an automatic risk evaluation model and, therefore, in reducing business process time, since risk evaluation is currently being carried out by people. The solution allows maintaining the anonymity of the data and using GAN to obtain different synthetic time series, increasing the data by 10%. It uses images from a vector of random numbers that are in temporal coherence and equal distribution. This research allows SMEs to obtain a greater amount of data, with a simple solution, to make better decisions.

Keywords: GAN · Times series · Fintech · Synthetic Data Generation

1 Introduction

The Fintech industry is based on three pillars: technological innovation, process disruption, and service transformation [1]. Although there is no consensus, the definition is "a company or subsidiaries of companies that combine financial services with modern and innovative technologies" [2].

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The evolution of this industry is commonly divided into three main periods [3]: Fintech 1.0: in this period one can find technologies ranging from transatlantic telegraph communication to ATMs; Fintech 2.0: one can find technologies ranging from the Internet to the Internet of Things; Fintech 3.0: data-driven technological innovations.

In all industries, although accentuated in the financial industry, the impact of digital technologies based on data, and in particular Artificial Intelligence (AI), is generating a structural change in the way business is conducted and organized [4]. This phenomenon is referred to in the literature as the Fourth Industrial Revolution [5].

In this scenario, large companies have a competitive advantage over small companies due to the amount of data they handle. For this reason, it is debated whether it affects free competition [6].

The industry is faced with privacy requirements, at least the anonymization of information before its use by internal or external teams [7, 8].

These difficulties, the lack of large volumes of data, and the need for anonymization have led to the need to generate synthetic data.

Synthetic data is defined as: "Any data used productively for a particular situation that is not obtained by direct measurement" [9].

The use of statistical techniques to share and study statistically relevant data, while preserving confidentiality, extracted from the US Census is discussed in [10]. Thus, it is proposed to use the same techniques used to impute missing data to generate a new series of statistically relevant data.

From the 1990s until 2010, the discipline of data generation was dominated by statistical models; these types of methods produce a steady increase in model complexity and require the use of complex correction methods in addition to non-linear or non-standard analysis [11, 12].

With the advent of AI, particularly computer vision, synthetic data generation is not only being refined but also extended to the use of simulated environments. The increased detail of three-dimensional models has succeeded in replacing real data for successful model training. The variability ranges from object recognition to face recognition [13, 14].

One of the main methods for data generation is Generative Adversarial Networks (GAN), a method that consists of training two models simultaneously, a generation model and a discrimination model [15]. In this case, the generation model is fed with a noise component to ensure its variability and is trained to generate a data set that follows the same distribution as a previously defined set. The discrimination model is trained to distinguish when a data set matches the ensemble and when it does not. Training ends when the discrimination model is unable to effectively distinguish whether a data set is synthetically generated or part of the originally defined set [16].

Although this type of model is successful in generating synthetic data, it shows weaknesses in generating time-dependent data [17]. This leads to the development of new GANs that allow the generation of synthetic time series [18, 19].

In the financial industry, time-dependent data or time series are highly valued and are mainly used in machine learning and forecasting models [20–22]. This information allows them to evaluate different scenarios and make better decisions. However, this

type of information is costly and difficult to obtain for SMEs and companies that have only been in business for a few years.

Our research aims to generate synthetic time series using a GAN model, this research of exploratory type, with an Action Research approach [23]. It uses a design science methodology and is associated with a fintech that supports small and medium enterprises (SMEs) by providing financing solutions. The business objective is to reduce the duration of the factoring finance delivery process, for which it is necessary to synthetically increase the amount of data by 10%.

This paper is structured with this introduction, Sect. 2 presents a background and related work. Section 3 describes the methodology, the decisions and methods used in our development, then Sect. 4 reports the results and discussions, and Sect. 5 is a summary of conclusions, limitations, and recommendations for future work.

2 Background and Related Work

GAN research in finance is still in its infancy, mainly because GAN does not naturally model time series [24]. Research that combines different techniques with GAN (neural networks, ML algorithms, etc.) has been incorporated to model time series.

In [25], they aim to generate time series focusing on reproducing the statistical properties of financial time series. It takes 6 statistical properties of this type of series: 1) linear unpredictability, 2) thick-tailed distribution, 3) volatility clustering, 4) leverage effect, 5) coarse-fine volatility correlation, and 6) profit/loss asymmetry. To generate data sets with these properties, they generate three different GANs, one with a multilayer perceptron generator with four fully connected layers and a hyperbolic tangent activation function (MPL); another with a six-layer convolutional generator with a ReLu activation function (CNN); and finally a combination of both, where both layers are used in parallel and the final results are combined with an element-by-element multiplication (MPL-CNN).

The results of the above networks are compared with each other and with previous work to verify that they satisfy these properties. Thus, it is presented how to set up a GAN to preserve the relationships between the data of the GANs.

In [26], the authors address the problem of data imbalance, which occurs when data are divided into positive and negative data and causes a bias in the learning of the GAN. To the existing solutions, which consist in modifying the data set to reduce the more frequent part and modifying the objective functions to give more importance to the false cases, the authors propose the generation of negative data by a modified GAN.

To do this, they take a type of recurrent neural network, the Long-Short Term Memory (LSTM), and transform it into a neural network layer to preserve the temporal relationship of the data to a time series. Then they penalize the objective function obtained from the real data and the generated data, and finally, they use the Kernel Maximum Mean Discrepancy (Kernel MMD) metric [27], which allows them to evaluate the performance of the model.

In [28], the database contains fraudulent transactions with a class imbalance. A synthetic generation of fraudulent transactions is presented to improve the training performance of the models. The characteristics of the user and his transactions are used.

The neural architecture is divided into two parts, a fusion module that tries to mix these two types of data to leave them in a single homogeneous set, and a balancing module that allows to generate examples of fused data of fraudulent transactions. The discriminator of the latter module distinguishes between three classes: normal, fraudulent, and synthetic transactions.

Improving the performance of a neural model to discriminate whether an e-money transaction is fraudulent is the goal of the research in [29]. Therefore, the use of autoencoders is explored to extract features from the data sets, which are then fed to a model that discriminates whether the transaction is fraudulent or not. Given the imbalance of the data, an architecture with two information generators is created to improve the balance. The architecture considers three phases, in the first one they use a Wasserstein GAN (WGAN) [16] to generate synthetic fraudulent data, with the augmented dataset they go to a second phase where they train two autoencoders: one for the augmented fraudulent data and another for the benign data; with the trained autoencoders they start a third phase where they train a second generative network that generates data equivalent to those generated by the autoencoders as input for the final model. This study concludes that the use of dataset features improves the performance of neural networks, but they require a larger number of data to overcome the class imbalance problem. In addition, it applies the novelty of having two generative networks in sequence to perform its task and this not only does not affect the performance of the final network but improves it.

In [30], GAN is used to generate synthetic data in the financial domain, in response to the imbalance of data with fraudulent transactions, in this case, fraudulent transactions represent 0.185% of the total number of records. To complement the results, they train a discriminator purely with real data to compare with another model. The results of the study are compared with data generated by the Synthetic Minority Oversampling Technique (SMOTE) method [31]. They conclude that this method can be applied in the field of synthetic generation of financial data, with results similar to other methods.

In [32], they use conditional GAN to model financial time series; since conditional GAN requires a vector to label the data according to some characteristic. An experimental estimation is performed with the S&P 500 index, the cycles are analyzed, and the convergence of the GAN is evaluated, as well as its performance according to the chosen hyperparameters.

They then build three GANs, a small one (cGAN-Small) with 5 neurons in the discriminator (D) and the generator (G), a medium one (cGAN-Medium) with 100 neurons, and a large one (cGAN-Large) with 500 neurons each. They add to the GAN two types of basic learners (M) to be combined with the GAN: Reg Tree (Reg Tree) and Multilayer Perceptron (MLP), for which they use different numbers of instances (B) of the methods. For their evaluation, they use the Sharpe index, the Calmar ratio, and the RMSE.

The mathematical support for the use of temporal convolutional networks is provided by [24], who use stochastic volatility neural networks in the time series domain, evaluated on the S&P 500 index. In addition to the neural network presented, the information preprocessing pipeline is analyzed, where, in addition to the normalizations performed, an inverse Lambert transform is performed [33].

The authors propose an architecture using layers of extended convolutional neural networks. They compare the generated neural network models and their performance with respect to several metrics, including the Wasserstein distance, the Dragulescu and Yakovenko (DY) metric, and the ACF score (which measures the historical dependence of the data). They conclude that temporal convolutional networks outperform the autoregressive model with conditional heteroscedasticity (GARCH) and its C-SVNN variant for generating synthetic time series.

In [34], they address the problem of detecting fraudulent banking transactions, to overcome the imbalance problem, they augment the dataset with synthetic data. For data generation, they combine a GAN with a denoising autoencoder (DAE), a DAE is a special case of an autoencoder that adds noise to the input data (x) to then transform it into another data set (x') through a function (f). Training a DAE consists in minimizing the error between x and $f(x')$. The results show the usefulness of mixing different techniques to generate synthetic data, as well as the need to measure the degree of similarity between the two data sets.

3 Material and Methods

The methodology used is based on the science of design, using metrics that validate the previously defined objectives [35, 36]. This research is exploratory in nature and uses an Action Research approach [23] as a meta-methodology, since the focus will be on application in the organizational context, with the specific objective of improving a business process.

The programming language used is Python 3.8.5, on Anaconda version 2020.11. The following libraries used torch, tqdm and utils.

The original dataset consists of a list of 1,495 time series of length 512, corresponding to daily totals of issued invoices, each series generated by a different company. The dataset has been anonymized to avoid bias and privacy issues.

The fields with continuous values ($) were normalized by logarithm to smooth their effect. To measure the performance of the GAN generator, the following variables are considered: Comparison of the Fréchet distance of the generated time series with the existing ones, by random sampling; Comparison of the distance generated by dynamic time distortion of the generated time series with the existing ones, by random sampling.

The objective is to design and test a model that allows the generation of synthetic company sales data to support risk assessment and thus discriminate and accelerate the decision-making of financial partners.

To achieve the objective, the following tasks are required:

- Extract an anonymized sample of the data to be enriched.
- Design a model capable of generating synthetic company data.
- Implement the data generation model.
- Implement the data discrimination model.
- Generate synthetic data that is indistinguishable to the data discriminator.
- Implement a classification that allows visual comparison of synthetic and real data.
- Implement metrics to determine the closeness of the generated data to the real data.

The process for generating synthetic sales data is shown in Fig. 1, and Sect. 3.1 explains each step of its execution.

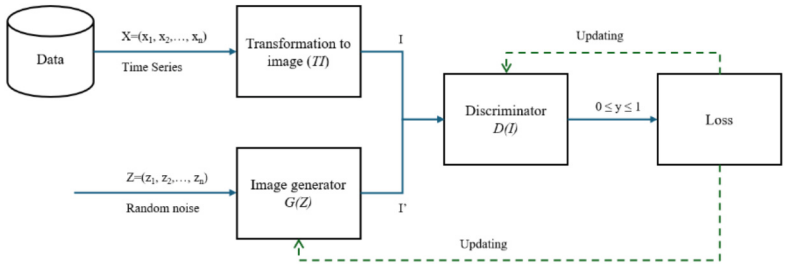

Fig. 1. Diagram of GAN components for synthetic data generation. Source: Own elaboration.

Once the tasks listed above have been completed, the direct impact on the specific objective will be measured.

3.1 Project Execution

First, a classification of the time series was made using the average sales and the number of days with sales for each company. It is observed that the average sales are less than one million CLP and less than 30% of the days with sales, the detail of the distribution is shown in Fig. 2.

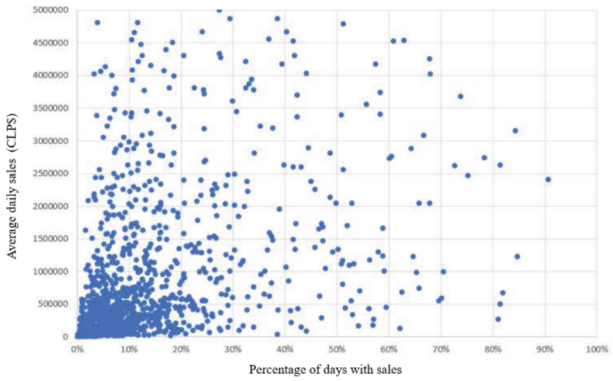

Fig. 2. Distribution of % of daily sales by company and daily average.

3.1.1 Transformation to Image

Then, each time series is transformed into an image. This procedure consists of a function (*TI*) that, after receiving a time series (*x*), returns an image (*I*). To represent the time series, an image of height and width (n = 512) is defined, where each row represents

one day of information. In addition, two channels are used: green and red. For green, the Graminian Angular Field (GAF) method [37] is used with the summation option [38, 39], the method allows to visualize of the distances that exist between each of the points of the time series, in this way the temporal relationships between the data are graphically preserved. In addition, the unnormalized logarithmically normalized value of the time series is added to each row of the image. To represent this value, the binary conversion of the number is performed and then this value is added to the red channel as 0 or 255, representing the zero or one corresponding to the binary value.

To generate the random noise, the rand function of the Python torch package [40] is used to generate random number vectors of the type $Z = (z1, z2, \ldots zk)$, where $zj \in \mathbb{R}$ and $k = 64$.

3.1.2 Image Generator

The generator (G) of the series corresponds to a function that generates images of size n x n, given an input Z, i.e. $G(Z) = I$. For the generated one, 4 linear layers are established where the ReLU activation function is normalized and applied, using the Python torch package. Finally, a final linear layer with a sigmoid activation function is added.

To represent the time series, an image of height and width $n = 512$ is defined, where each row represents one day of information. In addition, two channels are used: green and red.

For the green, the Graminian Angular Field (GAF) method is used with the sum option [38], this method allows visualizing the distances that exist between each of the points of the time series and in this way the temporal relationships between the data are graphically preserved.

3.1.3 Discriminator

A function is used as discriminator (D), which allows to indicate the degree of similarity with the real set of the synthetic time series, this is expressed in the following function $D(I) = y$ with $0 \leq y \leq 1$.

The degree of membership (y) of the discriminator allows us to update the weights of the generator and the discriminator, respectively, according to the loss function. Four sequential linear layers are designed, three of them with LeakyReLU activation function with a negative slope of 0.2 and a last linear layer. A hidden dimension size of length 128 is defined.

For the loss function, which measures the distance between the probability distributions, the cross-entropy function BCEWithLogitsLoss [40] is used. In the case of the discriminator, the average loss of this component is calculated with respect to its performance, i.e., the ability to correctly discriminate synthetically generated images and images belonging to the ensemble.

In the main execution function, the parameters that can modify the learning result, such as the number of epochs and the learning rate of the network, are received. In this function, the neural network is completed with the Adams optimization function [41, 42]. Then, for each of the training epochs, a batch of data is taken, it is determined whether the update of the discriminator occurs, the loss is calculated, and the nodes of

the neural network are updated. Later, the same is done with the generator, obtaining a generated data set, calculating its loss, and calculating the update of the nodes belonging to its network.

3.1.4 Loss

In general, generative adversarial networks attempt to replicate the probability distribution of a set in another synthetically generated set. To do this, metrics are used to measure the distance between probability distributions. This metric of the difference between the distributions is called the loss function or cost function.

Variables containing metrics are updated and their results are analyzed. In this neural network execution algorithm, depending on the input parameters, it is possible to update the discriminator and the generator in a differentiated way, which allows, if necessary, to omit the learning of the discriminator.

In addition, variations of the neural architecture are made to explore its use, integrating convolutional layers into the neural network architecture, given the high computational cost, surface convolutional layers are specifically chosen, however, these generated images of low quality and resolution, not representing time series.

To solve the above problem, the complexity of the convolutional layer is increased, it is trained and after 24 h of continuous work, it is calculated that the complete training can take between 3 and 4 months, therefore the execution of this experiment is abandoned.

In the last additional test, the loss function used in the neural network is modified by the Wasserstein loss function, but it does not converge and gives lower results than those obtained by GAN.

3.1.5 GAN Execution

The main execution function receives the parameters that can modify the learning result, such as the number of epochs and the learning rate of the network. In this function, the configuration of the neural network is completed with the Adams optimization function.

Then, for each of the training epochs, a batch of data is taken, it is determined whether the update of the discriminator occurs and, if so, the loss is calculated, and the nodes of the neural network are updated, calculating its loss and calculating the update of the nodes belonging to its network.

In this neural network execution algorithm, depending on the input parameters, it is possible to update the discriminator and the generator differentially, which allows, if necessary, to omit the learning of the discriminator.

3.1.6 Hardware Infrastructure

Two machines are used in the design phase:

Processor: 2.2 GHz Intel Core i7 6-core 8th generation 64bit Intel Core i7; RAM Memory: 16 GB 2400 MHz DDR4 RAM; Video chip: Radeon Pro 555X 4 GB.

Processor: 1.6 GHz Intel Core i5-8250U 4 cores 64 bits; RAM Memory: 8 GHz 1866 MHz DDR4; Video chip 1: Intel UHD Graphics 620 and NVIDIA GeForce MX150 2 GB.

Plus a third AWS g4dn.16xlarge machine to run the experiment.
Processor: 64 vCPU's; RAM memory: 256GB; Video chip: 16GB.

4 Preliminary Results and Discussion

Twenty simulations were performed to generate the synthetic time series and to evaluate the different metrics obtained. Information from the other simulations has been omitted as they are the variations that showed the lowest indicators. The hyperparameters used in the most representative tests are shown in Table 1.

Table 1. Hyper-parameters for GAN execution and synthetic time series generation.

Hiper-parameters	First	Second	Third (*)	Fourth
Epochs (numbers)	250	500	125	75
Batch size	20	20	20	20
Noise vector size	64	64	64	64
Device	CPU	CPU	CPU	CPU
Learning rate	0.00001	0.00001	0.00001	0.00001

Note: (*) Represents hyperparameters with best results

The execution time was at least 5 h for each simulation, the memory usage varied between 98%–100% RAM usage. Due to the architecture used, it was not possible to use the available video card, only the CPU of the machine was used.

The third simulation was chosen because it gives the best distribution of results. From these cases, a sample of generated and real time series is taken and compared to establish their similarity and thus verify the validity of the generated data. The metrics chosen for this purpose are the Dynamic Time Distortion (DTW) [43, 44] and the Fréchet Distance [45].

The distribution of the time series is within the expected range in terms of the distribution of days with sales, as shown in Fig. 3.

When using the Dynamic Time Distortion method, distances are first calculated between a sample of the real time series to establish an expected base of diversity among the synthetic series. Similarly, the distances between the synthetic time series are calculated to establish the diversity in a generated universe.

Next, the exercise of calculating the distance between the real and synthetic time series samples is performed. In this way, the behavior of both can be compared. Table 2 shows the DTW values for the real and synthetic data. It can be seen that, although there is a difference between the observed distance ranges between the synthetic and real time series, the gap decreases when they are compared, and they reach values similar to those obtained when measuring the distance between real time series.

Similarly, the difference in the standard deviation between the distances collected between the real series and the standard deviations of the synthetic time series compared

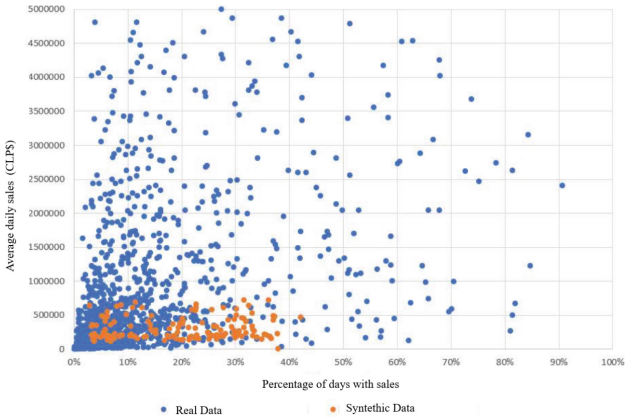

Fig. 3. Original and synthetic average sales comparison.

Table 2. DTW Data Trend Measure Summary.

	Min	Max	Average	SD
Real Data (RD)	56,588,519	329,227,381	204,915,746	55,488,325
Synthetic Data (SD)	39,133,762	276,994,524	158,807,390	69,230,463
RD v/s SD	66,032,324	339,255,910	203,836,510	65,819,000

to the real ones shows a gap evidenced by time series concentrations that account for little variability.

Understanding that the comparisons are relative, a normalization of the distance data is performed, with respect to the maximum of the set. With the normalized data, Table 3 is created, which groups and counts the distances at regular intervals in order to analyze the distribution of the occurrences of the normalized distances.

The distribution in the normalized intervals, and the synthetic time series tend to have a lower variability distributed in all the intervals, causing some concentrations of these. Most of the distances are in the interval 0.4 to 0.9, concentrating the distances in a higher interval than observed in the behavior between real time series distances, which are more distributed throughout the interval. This shows a low variability in the generated series.

The distribution between both series has similarities in its distribution, despite not being aligned, they are not different distributions, but the same type of distribution in a different interval.

When evaluating the Fréchet distance, it is observed that the distances of the generated series are within the real ones. Table 4 shows the minimum, maximum, average, and standard deviation values. From these data, it can be concluded that the distances of the generated series are within the real ones for the synthetic data set and for the synthetic data set versus the real data.

Table 3. DTW frequencies relative to maximum.

Interval	Real Data (RD)	Synthetic data (SD)	RD - SD
0–0.1	0	0	0
0.1–0.2	1	25	1
0.2–0.3	16	24	27
0.3–0.4	8	27	45
0.4–0.5	34	30	84
0.5–0.6	45	17	58
0.6–0.7	54	36	76
0.7–0.8	51	26	65
0.8–0.9	19	5	60
0.9–1	3	0	24

Similarly, the standard deviation shows that the synthetic time series have less variability between them, a result of the previous analysis regarding their classification. In addition, it is important to highlight that the maximum distance between two series is in the real data set, so no time series escapes the domain of the real series.

Table 4. Summary of trend measures of Fréchet data.

Conjunto	Min	Max	Average	SD
RD	941,033	30,277,974	10,235,362	6,475,263
SD	2,097,152	19,386,512	8,852,097	2,893,125
RD - SD	2,097,152	26,166,589	9,919,285	4,389,311

Since the comparison between the different distances is relative, and to facilitate the visualization of the results, the entire table is normalized by dividing the distances by the maximum distance. Table 5 is generated with the observed data and shows the frequencies at which the relative distances occur for each data set.

It is verified that most of the distances are accumulated between 20% and 60% of the maximum distance, another result of the low variability between the generated series, but they are reasonably distant from the real series and from each other.

From the evaluation of the best case, it is possible to state that the model allows to increase in the data by the expected 10%: from the original 1495 cases, 150 time series are generated, and distributed analogously to the original series.

It is important to note that the time series are not distributed over the entire available space; the values are strongly clustered in the range of less than $500,000 per day.

One possible cause of this is the way the time series are encoded; it is possible that the higher numbers are constrained by the approximation of the encoding of real numbers

Table 5. Frequencies of Fréchet distances relative to maximum distance.

Interval	Real Data (RD)	Synthetic data (SD)	RD - SD
0–0.1	14	4	22
0.1–0.2	56	25	66
0.2–0.3	51	86	116
0.3–0.4	38	49	121
0.4–0.5	27	21	65
0.5–0.6	13	3	33
0.6–0.7	13	2	7
0.7–0.8	9	0	8
0.8–0.9	6	0	2
0.9–1	3	0	0

between 0 and 1 to the discrete interval between 0 and 1 in order to obtain a binary encoding of the magnitudes.

This can be avoided by setting these values to one, but this distorts the time series towards higher magnitudes without having a valid basis for doing so.

On the other hand, analysis of the DTW and Fréchet distances confirms that the time series are distributed similarly to a subset of the original time series.

5 Conclusions

This research has focused on exploring a method to generate synthetic time series for the financial industry. A model capable of generating time series that respect the original distribution of the data is designed.

The strengths of the solution obtained are to maintain the anonymity of the data, i.e. it is not possible to deduce the original data from the generated data. Thus, it is possible to maintain the exportability of the data within the legal framework and to reduce the risk of information leakage.

The solution is easy to implement since the various GANs that solve the time series generation problem correspond to complicated amalgamations that use complex algorithms and optimizations to maintain the temporal coherence of the time series. This allows SME companies to have more and more information for decision-making.

Finally, since the model generates images from a vector of random numbers, it is possible to generate an unlimited number of time series that must be within the same distribution already discovered, so despite its limitations around the variability of the series, it provides a substantial amount of data to begin the development of a credit evaluation model. As a result, SME companies can have more and better tools to make them competitive.

This work is not free of limitations, the main one related to the high consumption of computational resources, which meant limiting the number of experiments to be

performed by modifying the hyperparameters to increase the variability of the time series generated.

On the other hand, the limitation related to the nature of the time series and its variability, so that the general shape of the series and its distribution may change over time so that in order to continue obtaining valid series, it is necessary to constantly train the neural network to adapt to changing market conditions.

Finally, the limitation related to the amount of data (real time series) with which we have worked should be extended to verify if there are changes in the results.

As a future development, it is proposed to perform tests with other time series on image encodings that are less dependent on the resolution of the generated image. In this way, modifications can be made using a recurrent neural network model with memory (RNNM model).

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Hybrid Information Security Framework Based on ISO/IEC 27005:2022 and the NIST Framework for the Ministry of Education of Ecuador (TIC)

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Abstract. Currently, the National Directorate of Information and Communication Technologies (NDICT) of the Ministry of Education (MOE) of Ecuador faces significant security management challenges. Within its IT structure, the entity has implemented information systems and optimized processes to automate previously manual tasks. This article aims to design a hybrid framework to address three key security issues through a thorough research review. Prominent vulnerabilities include weak passwords and the risk of unauthorized physical access. ISO 27005 and NIST 800–53 offer a robust approach to manage information security risks. Validating the framework and controls' applicability ensures suitability for specific infrastructure and operations. Security tests and simulations identify weaknesses, strengthening controls against cyber threats. Leadership approval is crucial for a proactive security improvement approach. This combination provides a comprehensive approach to security risk management, ensuring confidentiality, integrity, and availability of information and systems at the National Directorate of ICT. Following these guidelines prepares the department to address current and future security challenges effectively.

Keywords: ISO/IEC · NIST · Framework

1 Introduction

In the current digital environment, inadequate access to Internet networks and business applications poses a significant threat to information security. To address this challenge, organizations can turn to two widely recognized frameworks: the ISO/IEC 27005:2022 standard and the NIST 800–53 Framework. The ISO/IEC 27005:2022 standard is an international standard that establishes principles and guidelines for information security risk management. It provides a structured and systematic approach to identify, assess, and address risks associated with unauthorized access, as mentioned in the ISO/IEC

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27005 standard document [1]. By following the guidelines of the ISO/IEC 27005:2022 standard, organizations can implement appropriate security measures to protect their networks and business applications against unauthorized access. This involves the identification of critical information assets, analysis of threats and vulnerabilities, selection and application of appropriate security controls, and continuous monitoring of the security environment [2].

On the other hand, NIST 800–53, developed by the National Institute of Standards and Technology (NIST) in the United States, provides a set of security controls and recommendations for federal information systems [3]. This framework is based on risk management principles and provides guidance in areas such as access control, authentication, activity monitoring, and incident response [4]. The use of the NIST 800–53 Framework allows organizations to establish a robust foundation of security controls, taking into account internationally recognized best practices and standards. By combining the ISO/IEC 27005:2022 standard and the NIST 800–53 Framework, organizations can benefit from a comprehensive approach to address unauthorized access to their Internet networks and business applications. These frameworks provide a set of proven security controls, helping organizations identify and mitigate risks associated with unauthorized access [5]. By adopting these best practices and security controls, organizations can strengthen their ability to prevent and mitigate risks associated with unauthorized access, thereby protecting their critical information assets and ensuring trust and security in their digital environment [6].

The National Directorate of Information and Communication Technologies (NDICT) of the Ministry of Education (MOE), essential for educational modernization, it focuses on the effective implementation of information and communication technologies. It seeks to improve information accessibility and promote dynamic learning. Table 1 details the total number of registered students for the fiscal year 2022–2023, broken down by educational systems in Ecuador, guiding decisions in educational planning and management.

Table 1. Students enrolled in the Ministry of Education

	Coast - Galapagos	Sierra - Amazon	Levels
Baccalaureate	399,961	299,325	1ro, 2do, 3ero
Basic	1′405,997	925,955	1ro Básica a 10 Decimo
Total	1′805,958	1′225,280	3′031,238

Other Supports Information refers to Private, Fiscal-Commissioned, and Municipal institutions, with the information managed within the NDICT of the MOE, as shown in Table 2.

Table 2. Total enrolled students in Other Supports

	Total, Students Other Supports	Levels
Baccalaureate	204,315	1st to 3rd
Basic	716,888	1st Basic to 10th Tenth
Total	921,203	

Note: In the current data, the figures may increase as they are extracted during the enrollment process in the Sierra region

2 Methodology

Research focused on cybersecurity based on ISO/IEC 2022 and the NIST Framework. A qualitative approach and critical review of key articles will be employed. A validated framework will be designed within the NDICT systems to mitigate failures and vulnerabilities, particularly in the management of national student data, following the systematic review methodology known as SLR [7]. The research process was divided into four phases, detailed below.

2.1 Document Search

The following search string was used across various prominent scientific databases to locate documents related to the developing topic (refer to Fig. 1): ((“NIST computer security” OR “Information Security Risk Management Analysis Using ISO 27005” OR “Security Risk Management” OR “IS Analysis Using NIST “) AND (“Design of information security risk management using ISO/IEC 27005” OR “ security review “ OR “Assessing data cybersecurity using ISO IEC 25012”) AND (“Cyber Risk Management Planning Using NIST”)). In addition, variants were incorporated into the search strings with the aim of obtaining a minimum of 25 documents in each bibliographic database. In total, 40 relevant documents were retrieved in the area of interest.

2.2 Research Questions

To formulate the results, three research questions were addressed regarding challenges in Information Security, skills required for professionals in the field, and the role of auditing in data protection. Table 3 provides details and motivation for each research question. The information was gathered from specialized databases such as Science Direct, Scopus, IEEE Explore, Springer, and Google Scholar.

Table 3. Research Questions (RQ)

Number	Research Questions (RQ)	Motivation
RQ1	What are the most common cyber-attacks on computer systems?	Identifying and maintaining effective control over the most common attacks in the NDICT
RQ2	What are the recommended standards and regulations for mitigating computer attacks?	Proposing the application of norms and standards as a means to strengthen system security
RQ3	How to achieve more effective control and achieve high availability in information systems?	Detect vulnerabilities and address needs to achieve highly available systems

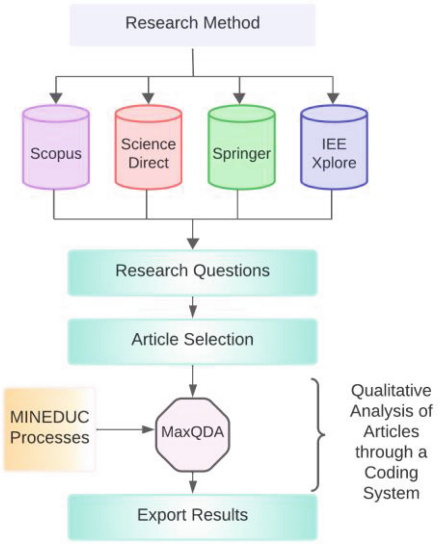


Fig. 1. Research Methodology.

2.3 Article Selection

In the article selection process, filtration criteria were implemented to choose documents obtained from research databases. These criteria addressed aspects such as content relevance, the inclusion of reviews, and their relation to cybersecurity and related topics. Additionally, during searches in bibliographic databases, an additional filter was applied covering classification by disciplines such as 'Science and Engineering,' 'Computer Science,' and 'Cybersecurity,' particularly in English.

2.4 Extraction of Relevant Data

At the end of the two document selection phases, 27 works were obtained. For the extraction of essential information from the Scopus, Science Direct, Springer, and IEE Xplorer databases, paragraphs were taken that helped answer the research questions using the MAXQDA qualitative analysis tool, following the guidelines proposed by Kuckartz in 2014 and the software specifications in 2019.

The articles analyzed with MAXQDA were organized into sections, labeling and extracting key data. They were grouped into areas of interest to design the research framework.

3 Analysis

In this research, a qualitative approach is employed through the collection of data from scientific journal articles and observations from the NDICT. A combined approach is used, integrating stages from the NIST Framework and ISO/IEC 27005:2022. The latest version of NIST 800–53, published in 2018, stands out for its improved organization in security areas, implemented through security profiles [8]. Its planned and business-focused structure makes it an effective tool to guide cybersecurity activities in risk management [9].

ISO/IEC 27005:2022 is a standard that provides guidelines for implementing a risk management approach to information security [10]. In this stage, ISO/IEC 27005:2022 is used to define priority and scope, thus establishing the fundamental criteria for the risk management process. This standard plays a crucial role in identifying assets, threats, vulnerabilities, and controls implemented by the organization [11].

Similarly, ISO/IEC 270005:2022 is used as a reference in the risk process, covering stages such as establishing context, risk assessment, risk treatment, and acceptance [12]. The results obtained in the cybersecurity risk management process undergo further analysis to provide control recommendations based on the NIST SP 800–53 standard [13].

NIST SP 800–53 is an assessment procedure and security controls for systems and information. It is used in the research due to its comprehensive reference [8]. Although it contains 20 control families, this study focuses on those necessary to provide control recommendations and enhance the security of the organization's information systems [14]. Figure 2 is an image of the flow of risk management stages along with the control recommendations used.

I. Prioritize Scope: In this phase, the scope is defined, and priority is established. The organizational structure, business objectives, mission, and priorities are identified. Fundamental criteria based on ISO/IEC 27005:2022, focused on the chapter of priority and scope include risk assessment, impact, acceptance, and risk treatment [15]. The data collection is done through scientific articles and observations of the NDICT and its processes.

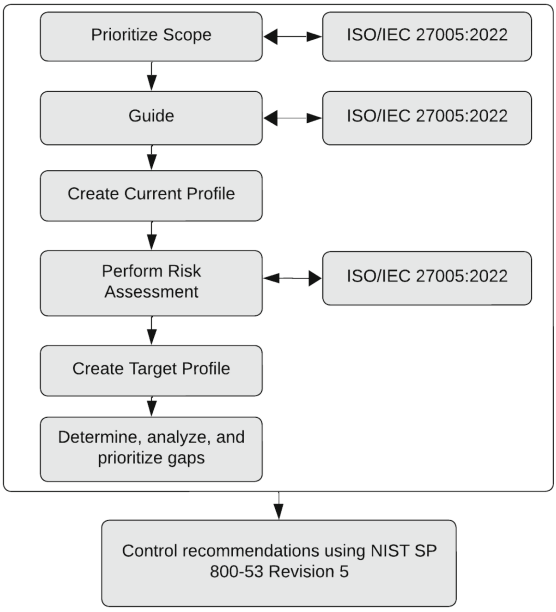


Fig. 2. Cybersecurity Risk Management Process and Provision of Control Recommendations.

II. Orientation: The stage aims to recognize resources and systems in the organization, identifying threats and vulnerabilities that affect assets. The process follows ISO/IEC 27005:2022 standard, in its risk analysis section, addressing the identification of assets, threats, vulnerabilities, and controls, as well as the analysis of the impact of posed risks [16].

III. Create Current Profile: This phase provides an insight into the perception and evaluation of cyber risk by the organization. Data were collected through scientific articles and observations of the NDICT and its processes. Evaluating perspectives on cyber risk involves positioning the organization according to the levels defined in the NIST Framework. [17].

IV. Conducting a Risk Assessment: This phase analyzes the operation of the organizational environment to identify and assess cybersecurity events, focusing on the MOE process. The risk assessment is divided into identification, analysis, and evaluation, followed by three additional stages: response, treatment, and prioritization, as depicted in Fig. 3. The results will guide treatment and control recommendations in the next management phase [18].

V. Create Objective Profile: In accordance with this phase, the aim is to define the objective profile that fits the specific needs and conditions of the organization. This profile is adjusted according to the levels established in the NIST [3]. Determining these levels ensures they are consistent with the organization's objectives, feasible to implement, and capable of reducing cybersecurity risks for critical assets of the organization [19].

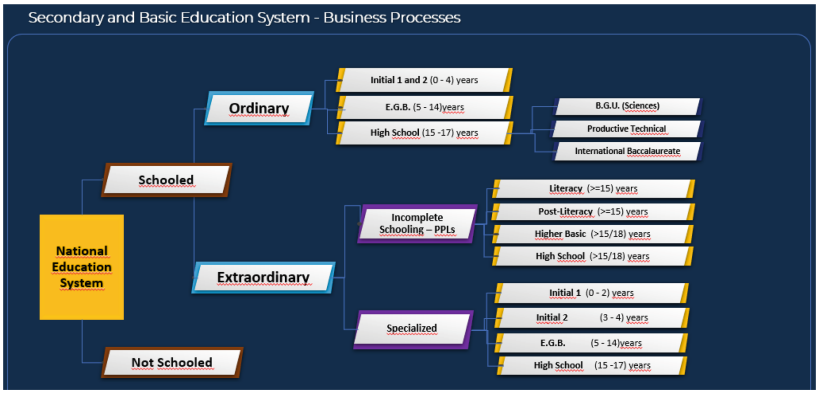


Fig. 3. Business Process - Ministry of Education (MOE)

VI. Determine, Analyze, and Prioritize Security Gaps: In this stage, profiles are compared, risks are analyzed, and a strategy is developed. The process at NDICT follows the EGSI, ensuring information security. Figure 4 illustrates the ISO/IEC 27005:2022 process [20].

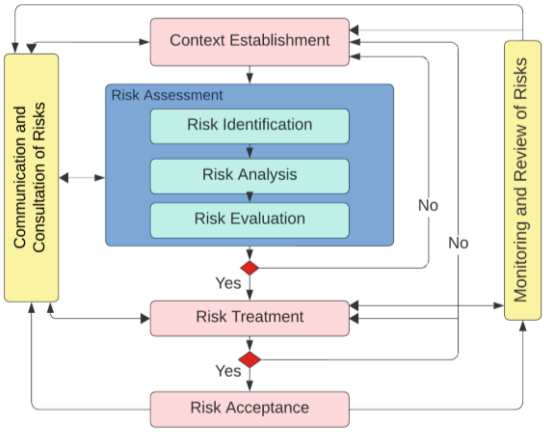


Fig. 4. ISO/IEC 27005:2022 Process.

Design of the Information Security Framework based on the comparison between ISO/IEC 27005:2022 and the NIST Framework from the NDICT of the MOE.

In this phase, the research focus at the NDICT shifts towards the planning of information security risks, based on the standards of ISO/IEC 27005:2022 and NIST 800–53. The relevant steps are detailed below, as illustrated in Fig. 5, according to the research questions. The resulting framework is presented subsequently:

Risk Assessment: ISO 27005 and NIST 800–53 are used to identify and manage risks. ISO 27005 focuses on analyzing assets, vulnerabilities, and assessing probability

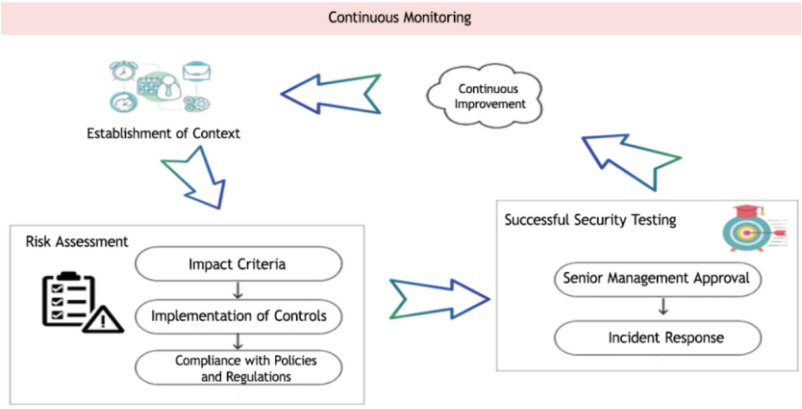


Fig. 5. Design of the resulting framework from the research.

and impact. NIST 800–53 employs controls such as authentication, access control, and encryption.

Evaluation Criteria for Risk: When assessing information security risks, key aspects such as strategic importance, asset criticality, operational interests, and stakeholder expectations must be considered. Additionally, impact criteria and risk events follow the guidelines of ISO 27005, as depicted in Table 4.

Table 4. Risk Probability Matrix

Probability of a threat event or occurrence	Probability that a hazard event will result in adverse impacts				
	Very low	Low	Moderate	High	Very High
Very low	Very low	Moderate	High	Very High	Very High
Low	Very low	Moderate	Moderate	High	Very High
Moderate	Very low	Low	Moderate	Moderate	High
High	Very low	Low	Low	Moderate	Moderate
Very High	Very low	Very low	Very low	Low	Low

Implementation of Controls: ISO 27005 and NIST 800–53 guide the implementation of controls based on the results of risk assessment. Measures such as multifactor authentication and robust password policies are applied to mitigate unauthorized access. In NIST 800–53, specific controls such as firewalls and intrusion detection systems are implemented to prevent unauthorized access.

Continuous Monitoring: ISO 27005: Establish a continuous monitoring process to detect potential unauthorized access activities on the network. Implement intrusion detection systems and audit logs to identify suspicious behaviors.[21]. NIST 800–53: Perform continuous network monitoring to detect unauthorized access attempts and anomalous activities [22]. Use security logs and alerts to respond promptly to potential incidents.

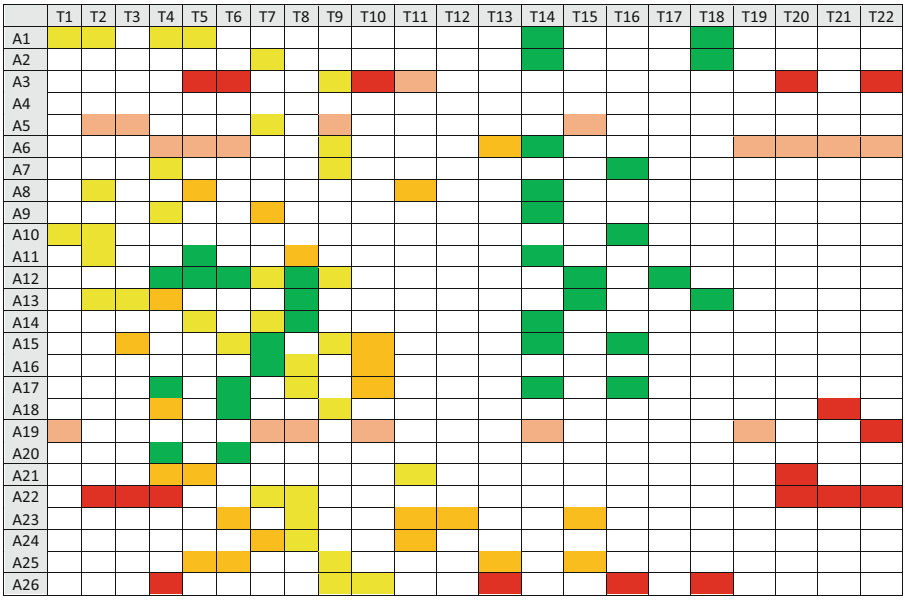
Asset Identification: Asset identification is carried out with the aim of determining the type of asset ownership and the value of the asset, a result obtained for 26 assets based on the results of risk identification.

Threat Identification: Identification of threats that could occur on each asset and threat source. A total of 22 threats that could impact the risk were identified.

Identification of Implemented Controls: Potential negative risks can occur due to vulnerability resulting from a lack of control over negative risks or controls that already exist but are missing or ineffective or inefficient in handling occurring threats.

Identification of Vulnerabilities: A total of 26 assets were identified, resulting in 126 vulnerabilities: 18 very high, 18 high, 23 moderate, 34 low, and 33 very low.

Table 5. Risk Assessment Value Matrix.



- Incident Response: ISO 27005 and NIST 800–53 require incident response plans, definition of roles, and mitigation procedures [23].
- Continuous Improvement: Both standards propose regular reviews and adjustments of controls to maintain network security.
- Security Testing: Tests are conducted to verify the effectiveness of the adopted controls according to ISO 27005 and NIST 800–53.
- Compliance: ISO 27005 and NIST 800–53 help comply with international standards and security regulations.
- Risk Assessment: It is based on impact and uses probability levels, highlighting high-impact risks. The risk assessment value matrix can be seen in Table 5.

Validation of the Designed Framework with Data Collected from the NDICT of the MIEDUC.

Risk Assessment: Critical assets of the ICT department, such as servers, workstations, databases, applications, and networks, are identified. Outdated servers used in the ICT department have not received the latest security updates, which could expose them to known vulnerabilities and exploits. According to prior authorization from the highest authority, network access is not properly controlled, increasing the possibility of an employee downloading a malicious file or opening a compromised link, potentially resulting in malware infection on workstations and compromising network security. Figure 6 illustrates the blockages within the MOE network.

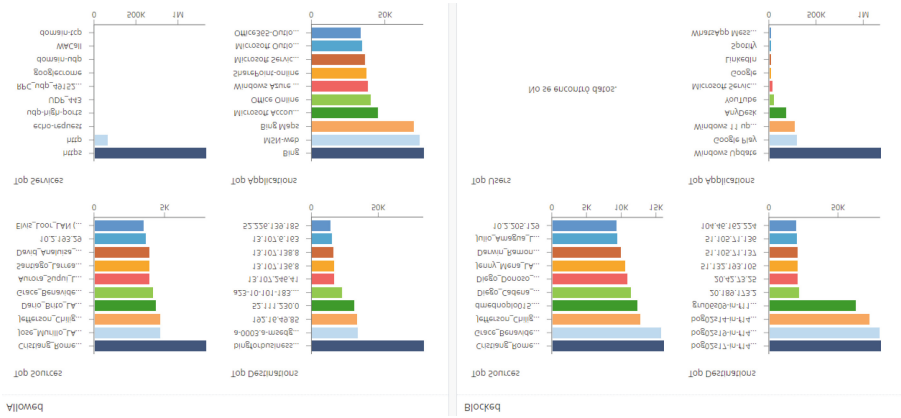


Fig. 6. Blocked Users and Pages within the NDICT Network.

Implementation of Controls: Proposal of controls based on risk assessment, including strong password policies and firewalls to strengthen security. Validating these controls through proof-of-concept testing will help mitigate risks and protect the organization's assets, following the recommendations of ISO 27005 and NIST 800–53.

Continuous Monitoring: Continuous monitoring verifies the effectiveness of implemented controls, identifies and mitigates emerging risks, and responds quickly to threats. It provides data for trend analysis and informed decision-making, as depicted in Fig. 7.

The NDICT of MOE responds to incidents with detection of unusual activity, risk assessment revealing vulnerabilities, and validation of the response through intrusion detection. Continuous improvement includes lessons learned, updating procedures according to ISO 27005 and NIST 800–53, and successful security testing.

4 Results

After conducting the validation of the resulting Framework based on the combination of ISO 27005 and NIST 800–53, the NDICT of MOE significantly improved information security and mitigated risks associated with unauthorized network access.

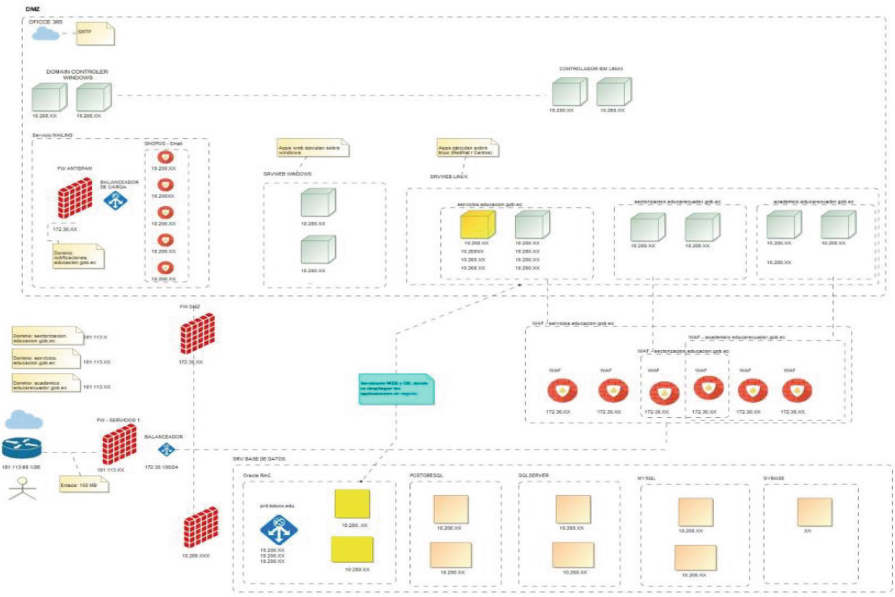


Fig. 7. General Infrastructure Diagram of Ministry of Education Applications.

Risk Assessment: A comprehensive risk assessment was conducted across the entire IT infrastructure, identifying key vulnerabilities and threats that could compromise the confidentiality, integrity, and availability of data and systems, as outlined in Table 6.

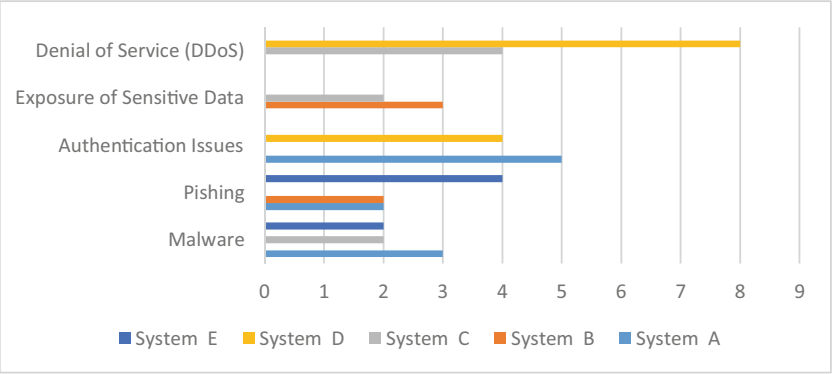
Implementation of Controls: Measures were adopted based on the assessment, such as multifactor authentication and strong password policies, aligning with ISO 27005 and NIST 800–53. Continuous Monitoring and Rapid Response: Establishment of a continuous monitoring system with intrusion detection and audit logs. Improvement in incident response for quick reactions to threats and prevention of institutional failures, as shown in Table 7.

Using the TOAD tool (Tool for Oracle Application Developers), transaction times and interruptions are extracted. As shown in Table 8, it is possible to identify peaks susceptible to system downtimes during registration and update processes.

Successful Security Testing: Penetration tests and vulnerability assessments were conducted, demonstrating the effectiveness of the implemented controls. Vulnerabilities were identified and addressed before they could be exploited. Table 9 analyzes the before and after of the research in the NDICT.

Responsibles: The Security Advisory Committee leads the implementation of the new research framework, providing guidance to the highest authority in information security. The Information Security Officer proposes key documentation for the framework, ensuring compliance with institutional standards and controls, and ensures continuous alignment of the framework with the objectives of the NDICT of the MOE, as seen in Fig. 8.

Table 6. Statistics of Vulnerabilities in the Main Systems of MOE.



System A: Grade Reporting System.
System B: MOGAC System.
System C: COLMENA System.
System D: Enrollment System.
System E: Teacher Assignment System.

Table 7. Statistics of Failures due to Attacks in the Period March-November 2023.

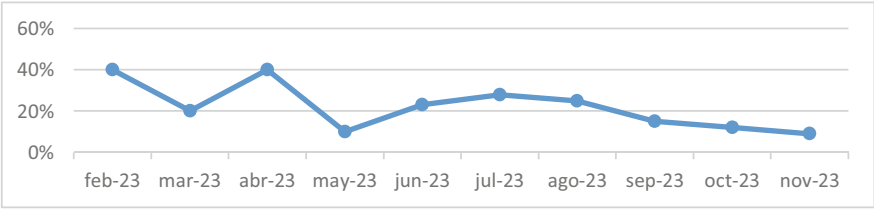


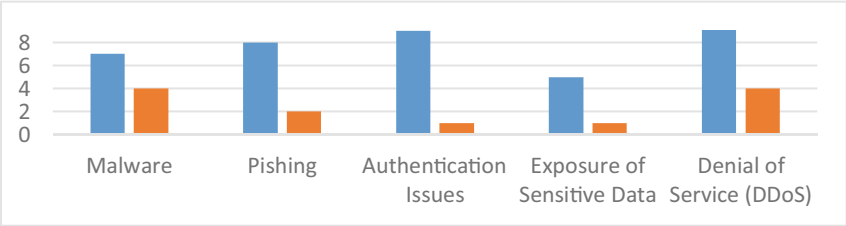
Table 8. Transaction Times and System Downtime-Prone Interruptions.

	Transaction Peak Points Coast - Galapagos	Transaction Peak Points Sierra - Amazon	Transaction Type
Baccalaureate	220,000 approx	180 000 aprox	Insert
Basic	125,000 approx	90 000 aprox	Update

Note: The number in the Sierra-Amazonia period may increase by approximately + - 8 thousand records in entries and updates as the data is extracted during the enrollment period

After validating the ISO 27005 and NIST 800–53 framework, the NDICT of MOE improved security and mitigated risks. They identified vulnerabilities, adopted measures,

Table 9. Before and after the attacks detected after the validation of the proposed Framework.



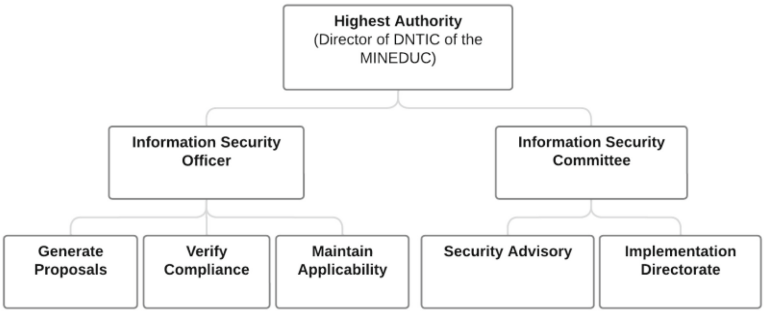


Fig. 8. Organizational chart of responsibilities according to the validation of the Framework.

established continuous monitoring, conducted penetration tests, and ensured regulatory compliance. The support of top management ensured effectiveness and cost control.

5 Conclusions

In the National Directorate of Information and Communication Technologies (NDICT) of the Ministry of Education (MOE), information security is of utmost importance to protect the organization's critical assets, data, and systems against potential threats and unauthorized access. The combination of ISO 27005 and NIST 800–53 provides a robust and comprehensive approach to manage and effectively mitigate information security risks. During this critical period, validating scenarios and attacks was challenging due to the constant change of information, as the Ministry of Education was in the process of enrolling and registering students in the different educational modalities and regimes in Ecuador.

It is concluded that the combination of ISO 27005 and NIST 800–53 provides a comprehensive and robust approach to information security risk management at the National Directorate of ICT of the Ministry of Education. By following these guidelines, the department will be better prepared to address current and future security challenges, ensuring the confidentiality, integrity, and availability of information and systems. This guarantees effective protection against potential unauthorized access and cyber threats.

Additionally, future research could explore the adaptation of security standards to specific environments. Investigating how to tailor and implement ISO 27005 and NIST 800–53 security standards to the unique infrastructure and operational requirements of diverse educational and governmental organizations would provide valuable insights. This line of inquiry aligns with the proactive approach advocated in the conclusion, ensuring that security measures remain effective and relevant amidst evolving challenges.

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Waterfronts in the Straits Port Areas, Between Architecture and Town Planning

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Abstract. The architecture and waterfronts of the straits are areas of environmental and landscape significance: coastal fronts on "fuzzy" limits, they are the last curtain of the existing city and the open fronts in a dialogue beyond. A strait has, by definition, the water and then the built-up area opposite. In the essay, which has the character of a literature review, we ask what the relationships of the land-sea borders are, what are the processes of transformation and management of architectural and urban dynamics. What are the speeds and possible spatio-temporal synchronies of visions and strategies. With reference to the straits of Europe, and particularly the Strait of Messina, one wonders if it is already possible to glimpse signs of a reorganisation of the territories in view of hypotheses of strengthening port realities or the realisation of a stable crossing.

Keywords: waterfront architecture · waterfront regeneration · waterfront design · Strait landscape · Strait of Messina

1 Introduction

Today it is very topical to reflect on the role of coastal cities and coastal facades of the Strait of Messina, but it is also appropriate to rethink the relationship between the city and the sea. It means looking at the past by identifying the historical reasons for a happy (or lacking) dialogue, but also turning our gaze to the present and the future. Going very far, it is Aristotle who identifies in the manuscript "Politics" what represents the ethical basis of an ideal city. In addition to arguing about the assumptions for good governance, based on the "civil consortium", he dwells on the need for the city to have contact with the continent and the sea [1] as the position "between the land and the sea" would benefit the "well-governed cities". During the Hellenistic period, in which the urban planning rules developed during the fifth century according to the teachings of the Hippodamians were applied, some cities attributed centrality to the link with the coast and the sea. Delos is an example. The island took on a new urban physiognomy, the agoras multiplied: in

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the second half of the second century B.C., the agora of Theophrastos were added to that of the port. The areas dedicated to commercial bargaining were created - among which the Hypostyle Room in the area adjacent to the port - and the port warehouses were created. The city is strengthened around the port. Among the Ptolemaic cities, Alexandria, which presents the regular Hippodamian scheme around Portus Magnus and Porto Eunosto, becomes an example of urban planning for the Ptolemaic cities within the territory and on the coast. Ptolemais was open to the sea with a harbour and had two wide streets perpendicular to the coast, which served the traffic between the city proper and the port [2]. With a time span of more than 2400 years, we arrive at the present day and the scenarios that can be hypothesized in view of the stable crossing of the Strait of Messina invite us to look at the process of socio-economic integration and territorial rebalancing that could be activated, at the interconnection of trade agreements that have their rationale in the "European/Mediterranean neighborhood policy" [3] between European states and the Mediterranean. The question arises as to whether the coastal cities of the Mediterranean basin, seen in their connection with the port, are configured as the physical tools functional to the port or as autonomous systems, as gateways or wings. In very different historical moments, Europe has focused on the outlets to the sea, encouraging the improvement of the internal infrastructure network, aware of the role that it assumes in the system of international trade, but has given little emphasis to an appropriate policy for the enhancement of coastal strips and their relationship with ports. But we are aware that coastal strips in general and coastal cities – in the double and different declination of port cities and cities with ports – have many complexities and criticalities to be addressed, as they are characterized by a variable geography and a dynamic geometry of flows. As it is difficult, as we will see in the paper, to propose a classification of the morphotypes of cities and identify appropriate tools for the integrated management of coastal areas and even arrive at unambiguous definitions of coastal strips. The definitions proposed over the years, starting with that of the U.S. Coastal Zone Management Act of 1972, have limited themselves to configuring it as an area of interaction between land and sea, without specifying either the nature or the scale of interdependence indicated, this limit is to be attributed to the fuzzy nature of the reality we are analyzing.

2 Cities in the Straits of Europe, Review

Cities located along the straits of Europe represent places of special interest from an environmental, landscape and urban planning point of view. Straits, such as the famous Straits of Messina, are geographic spaces characterized by the presence of water separating two lands, creating a strong connection between the two sides and influencing the urban and architectural development of neighboring cities.

The architecture and waterfronts facing the straits form a kind of barrier between the existing city and the sea, representing the last curtain of the city and opening up to open horizons and dialogues beyond land boundaries. These waterfronts prove crucial to the environmental and landscape quality of cities, as they define their image and relationship with the surrounding marine environment.

In the context of the straits of Europe, several cities overlook these unique spaces, offering interesting insights into the relationships between land and sea, as well as the

architectural and urban transformations taking place. For example, the city of Gibraltar, located in the Strait of the same name, represents a strategic crossing point between the Mediterranean Sea and the Atlantic Ocean, with architecture that reflects the history and cultural influences of different civilizations that have followed one another over time [4]. The city of Istanbul, positioned on the Bosphorus Strait, is also a significant example of a city in the straits of Europe. Its unique geographical location has fostered the development of a rich architectural history, with buildings directly overlooking the water creating striking cityscapes [5]. About the Strait of Messina, there are interesting signs of territorial reorganization in view of hypotheses of strengthening port realities and the realization of a stable crossing. The cities of Messina and Reggio Calabria, located at either end of the Strait, are facing major challenges related to the management of architectural and urban dynamics, seeking to enhance their waterfronts and promote greater integration between the two sides.

An analysis of the literature on the topic of land-sea boundary relationships in straits, with reference to the straits of Europe and the Straits of Messina, reveals a complex interaction between environmental, landscape, architectural and urban factors. Straits constitute spaces of transition and connection between two worlds, land and sea, and present unique challenges and opportunities for urban management and development.

The processes of transformation and management of architectural and urban dynamics in straits are crucial to preserve the balance between nature and the built environment, as well as to foster proper integration between local communities and maritime contexts. The search for possible spatial-temporal synchronies in the visions and strategies adopted is crucial to ensure effective and sustainable urban and spatial planning.

Specifically, looking at the Straits of Europe and the Strait of Messina, the need emerges to identify signs of a potential reorganization of the territories to promote hypotheses for the strengthening of port realities or the realization of a stable crossing. This process implies an in-depth reflection on the economic, social, and environmental dynamics that characterize these areas, as well as on the enhancement and protection of the cultural and landscape heritage.

Messina represents an interesting case study for the implementation of waterfront redevelopment strategies to enhance the city's historical and cultural heritage and improve the quality of public spaces along its coastline. A landmark study addressing the issue of waterfront redevelopment in Messina [6] analyzes the waterfront redevelopment project in Messina, focusing on the aspect of integration between the natural environment and the urban environment, and the importance of enhancing the coastal landscape to promote the sustainable development of the city. In their study, the authors analyze the Messina waterfront redevelopment project, focusing on the fundamental aspect of integration between the natural coastal landscape and the surrounding urban environment. This approach aims to enhance the environmental and landscape features of the coastal area to promote sustainable development of the city and improve the quality of life of its inhabitants. The importance of considering the coastal landscape as a key element in urban redevelopment is highlighted, as it represents an opportunity to create attractive public spaces, promote city-sea interaction, and preserve the biodiversity and environmental quality of the area. The enhancement of the coastal landscape not only contributes to the aesthetic and functional appearance of waterfronts but can also promote

the development of economic activities related to sustainable tourism and the enhancement of natural resources. Through their detailed analysis of the Messina waterfront redevelopment project, they highlight the importance of adopting integrated approaches that consider urban, environmental, and social dimensions to promote harmonious and sustainable development of the city. The enhancement of the coastal landscape thus becomes a key element in urban regeneration and the promotion of a healthier urban lifestyle in harmony with the surrounding environment.

Gibraltar is committed to the sustainable management of waterfronts through projects for the redevelopment of port areas, the creation of pedestrian paths along the coast, and the enhancement of the area's natural and cultural resources. Strategies for integrated waterfront management in Gibraltar aim to ensure balanced economic growth, preserve the marine ecosystem, and promote collaboration among different local entities for shared and participatory land management. A landmark study addressing the issue of integrated waterfront management in Gibraltar [7] highlights the integrated management strategies adopted to preserve the coastal environment, focusing on the importance of integrated coastal zone management, which involves collaboration among different actors, such as local authorities, nongovernmental organizations, local communities, and the private sector, in order to effectively and sustainably manage the natural and cultural resources of waterfronts. The integrated management strategies adopted in Gibraltar include the implementation of coastal development plans that consider environmental, social, and economic aspects, the promotion of marine and terrestrial biodiversity conservation, and the creation of synergies between the different activities carried out along waterfronts to maximize benefits and reduce negative impacts on the environment. In addition, an emphasis on the inclusion and active participation of stakeholders in waterfront planning and management is critical to ensure a transparent and democratic decision-making process that considers the needs and perspectives of all stakeholders, thereby fostering the long-term sustainability of waterfront redevelopment and development initiatives. Through their detailed analysis of the case of Gibraltar, Balaguer and Moya demonstrate how cooperation between different actors and integrated waterfront management can lead to positive results in terms of environmental conservation, sustainable development, and local community involvement.

Istanbul represents a prominent case study for urban regeneration and cultural enhancement strategies of waterfronts, given its unique location spanning two continents and overlooking the Bosphorus Strait. A landmark study that delves into the urban regeneration strategies adopted in Istanbul [8] is Istanbul represents a relevant case study for urban regeneration and cultural enhancement strategies of waterfronts, given its unique location spanning two continents and overlooking the Bosphorus Strait. A landmark study that delves into urban regeneration strategies adopted in Istanbul analyzes how the redevelopment of Istanbul's waterfronts has transformed these areas into creative urban spaces, promoting social and cultural interaction between residents and visitors. In their study, they examine the redevelopment process focusing on the aspect of urban creativity and the importance of promoting social and cultural interaction between residents and visitors. The authors analyze how the transformation of coastal areas has helped to create vibrant and inclusive public spaces, encouraging local community participation, and fostering cultural exchange. Through detailed analysis of specific case

studies in Istanbul, the authors highlight strategies implemented to enhance waterfronts as places of encounter and cultural expression. These strategies may include creating accessible public spaces, promoting cultural and artistic events, restoring historic and architectural sites, and raising awareness of the importance of environmental and cultural protection. The paper thus provides a clear perspective on the urban transformations that have occurred in Istanbul through the regeneration of waterfronts, highlighting how the enhancement of these coastal spaces has contributed to improving the quality of life for residents, promoting sustainable tourism, and preserving the city's cultural identity (Fig. 1).

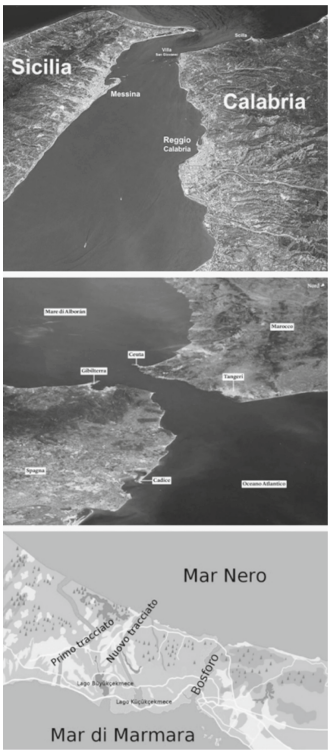

Fig. 1. The Strait of Messina and the Straits in Europe. Source: https://www.internazionale.it/magazine/2023/07/20/lo-stretto-di-gibilterra; .

3 Coastal Cities and Coastal Facades of the Strait, Such as Works and Infrastructures in View of the Bridge

Today, the aspects related to the port and the routes of the Mediterranean Sea seem to be experiencing a moment of rebirth, leading to a review of the physical/spatial configuration of the European territory and to extend interests beyond the physical dimension

of the urban context. With respect to the morphotypes of coastal strips, port cities and cities with ports, which will be discussed later, there is a heterogeneous case history. Decisive, with respect to this interpretation, is the role that the port is called upon to play. It is not necessarily the central place of the industrial system, of the material activities connected to it, it is rather a complex infrastructure, a node in a transport cycle, a gateway to territorial systems [9]. "Ports are therefore gateways to the world for territorial systems in the processes of globalization, in the face of a transport cycle that materially innervates the territory, is articulated in networks, and disperses into regional structures that are less and less dense" [10]. The gateway to the hinterland is the city, the settlement system that is physically and functionally welded to the port. Barcelona represents a significant case of a port system intended as a multimodal gateway to access a territory, the value of the strategic plans activated testifies to the scope of the interventions - which combine economic development, urban planning, and environmental protection - implemented through a Project Plan of considerable value. The Llobregat Delta is the subject of an artificial detour to allow the expansion of the port, the creation of a river park along the Rio, the construction of the South Gate through the Ronda de Dalt. The port system of Livorno is also an autonomous reality, characterized by the presence of wetlands and waterways that require safeguarding and protection interventions. The vast Pisa-Livorno area is in a central position with respect to both the Northern European and Mediterranean markets. The system of the logistics platform interacts with the San Rossore National Park and in the Park's Territorial Plan an attempt is made to restore the water-land relationship. The general Masterplan of Saranda, Albania, also indicates the direction of new infrastructural works – in particular the new access system to the city, the marina, accommodation facilities served by the new tourist service parkway, a fundamental option for the economic development of the country [11].

In the literature we have heard, with adequate clarifications, of coastal cities and coastal strips, the latter defined as that part of the earth's surface where the sea and the land meet (Carter 1988) [12], (Hildebrand and Norrena, 1992) [13]. The coastline can be described as a geographical feature with indeterminate boundaries, which is why it becomes difficult to apply the same metric of measurement and evaluation to all land and sea territories (Forman, 1995) [14]. And that's not all. Coastal cities, precisely because they are part of the generic, as well as complex, category of coastal areas, are areas of particular sensitivity and danger compared to other territorial areas. Floods, erosion and climate change with rising temperatures that progressively raise the sea level by reducing the land and the surface of the islands (as in Venice known as a lagoon city, it is organized around the central core of the island while there is another part that extends along the coast of Mestre and Porto Marghera), These are concomitant factors that lead scholars to investigate mitigating the possible damage caused by natural events (in any case related to human activities), rather than discouraging and discouraging some human practices and interventions. The expression 'coastal strip' acquires different meanings in different territorial contexts and in different disciplinary areas. Its definition can be found in the literature when it takes on the character of an "environmental emergency", i.e. a cogent issue that requires urban and environmental planning in line with the principles of sustainability. These approaches, known internationally as Integrated Coastal Zone Management (ICZM) (Cicin-Sain 1993) [15], have taken on different forms. This

is what the American Zadeh (1965) would have defined as fuzzy, a vague, nuanced concept. In fact, looking at the coast, it is not possible in scientific terms to say where the beach stops and where the sea begins. And then there is the coastal city, with the port cities and port cities. The latter are quite different from each other, as we will see later. If it is therefore difficult to schematize seaside cities into categories, starting with their "contiguity position" with respect to areas of different productions, but also to the different means of transport used on land and at sea, it is even more complicated to try to define the different morphotypes of coastal cities. It was probably the revolution of transport – protagonists of the changes in the way territories are used – that influenced the reorganization of the values and destiny of cities in the past. Among the seaside towns there are also those that lap the mouth of a river basin. Many of the cities established on "estuaries" or near "submerged valleys" are cities in which port activity and trade flows are predominant (Matvejević, 1987) [16], conditioning the settlement and urban organization of cities.

"The mouths of rivers have a double aspect: on the one hand it is the river that penetrates the sea, on the other it is the sea that enters the territory. The deltas at certain points make us discover the nature of their reciprocal relationship" (Matvejević, 1987) [16]. Cities such as Hamburg, London, New York and Buenos Aires allow maritime navigation to the interior of the territory. The cities built on the "deltas" of navigable rivers are less favourable to maritime ports, sometimes the deep ramifications have made possible the installation of port systems, among these we mention Rotterdam, New Orleans, Saigon. In general, however, the peculiarities of estuary cities define an osmotic urban landscape of contamination between river and sea water lines, compared to those of classic coastal cities. To the second group of seaside towns belong those landlocked coastal towns, whose position may have been determined either by the ease of sea access or by the guarantee of defence against the hinterland. As stated by Matvejević, "the nature of the port depends on the way in which the sea is in it, on the subjects to which it is accessible: the Atlantic or the Pacific are the seas of distances, the Mediterranean is the sea of proximity, the Adriatic is the sea of intimacy [16]." The condition of insularity, such as Singapore, Hong Kong, or Gibraltar, has favored the development of "cities of maritime empires" such as the English one. If, on the other hand, the condition of isolation derives from the orographic condition, such that the coastal city is bordered by numerous reliefs, as in the case of Rio de Janeiro or Genoa, and are partially sheltered from storms and surrounded by slopes, the condition of opening to the sea is natural [17]. "Cities with ports are distinguished from port cities. In the former, the ports were built out of necessity [18], in the latter they were created according to the nature of the place" [19].

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Fig. 2. The Samonà plan of the 1970s. Source C. Fazia

An analysis of the coastal façade between Cannitello (Villa San Giovanni) and Punta Pellaro (coastal town of Reggio Calabria at the extreme south of the coast) reveals that the coastal strip has been affected by numerous interventions for several decades, some almost completed, others in the process of being carried out. Villa San Giovanni [20], has been preparing for some time to reorganize the port infrastructures while waiting for the stable crossing to become a reality. The port project is part of a large project to upgrade the intermodal hub of Villa San Giovanni and is closely connected to the redevelopment project of the railway station. It is aimed at rearranging the external areas of the new piers, constructing a new building to serve as a passenger terminal and creating canopies to protect pedestrian flows between the railway station. Inside the building there are the various functions at the service of passengers. The building is the final element of the new project and in continuity with the interventions that RFI will carry out on the Villa San Giovanni railway station, allowing the creation of an intermodal rail-maritime hub in Villa San Giovanni. In the meantime, the waterfront project was launched in Villa, returned to the city with the enhancement of Piazza delle Repubbliche Marinare, the islet, Piazza Chiesa di Cannitello [21]. From the port of Villa San Giovanni to that of

Reggio Calabria, the projects underway concern the coastal stretch of Catona where the modernization of the seafront has begun. Continuing the analysis from north to south of the coast, the other intervention to be reported is the one concerning the Port of Reggio Calabria. In 2022 Atelier(s) Alfonso Femia took on the task of designing the masterplan that will connect the port with Zaha Hadid's Museum of the Mediterranean, this work - financed with PNRR funds - will be built on the Ponente pier. On the other side overlooking the Strait, there will be the MAXXI Med, for the arts of the Mediterranean and will house a research center. The redesign of the Reggio Calabria waterfront, which in Zaha Hadid's initial project also included the Functional Hub to be located behind the Central Station, represents a segment of a unitary program that concerned the seafront of Pellaro - with the Parco del Vento - and San Gregorio and intercepting the linear park that affects the southern area. To the north, the redevelopment of the Catona and Gallico waterfront stops before the port.

The South Linear Park is in the Calamizzi area. It stops at the airport, which is currently undergoing a major upgrading and renovation project. The seafront of Pellaro is affected by interventions that involve urban redevelopment and the arrangement of green areas. This will connect to the Parco del Vento which affects Punta Pellaro.

4 From Cities to the City of the Strait of Messina: For a New Waterfront

The urban and architectural conformation of the sea fronts of the three Strait cities - Messina, Reggio Calabria and Villa S. Giovanni - are strongly, and even heavily, marked by the continuous crossing. If in the past this gave rise to decidedly extraordinary results, such as the astonishing *Teatro Marittimo* or the Messina *Palazzata*, an exceptional seventeenth-century architectural invention with an urbanistic dimension, placed (in place of the original city walls) like an amphitheatre to frame and encircle the entire historic and natural Sicilian port of call, on the contrary, in recent years the crossing seems to have marked the two shores, leaving traces that are less and less respectful and rather treating the places almost as if they were roadside cafes (Figs. 3 and 4).

Yet the Strait, as it is in fact already partly experienced, is a complex inter-regional metropolitan system that certainly deserves more care and attention, especially in its precious, though never sufficiently appreciated, land border. Fewer crossing spaces and more public places and spaces where to stay, entertain and station, on the precious and never valued edge of the sea.

One suggestion would be to look at good practices from other Straits in Europe and around the world, useful for understanding which processes and phenomena 'cross' them, which works, which urban and territorial strategies and architectures they intercept or lap up. "Sea 'straits', such as the Bosporus, the Dardanelles or Gibraltar, unleash incredible energies, and one realises that the strength of their peculiarities lies not only in their function as natural links between two shores, but also in their role as channels for flows and energies."

Therefore, it is precisely in view of the construction of the bridge that it appears necessary to rethink the areas of the Strait's sea fronts, coasts and cities, with the related inland areas, on a vast, even interregional, scale, but with new eyes: as if the gaze were



Fig. 3. Reggio Calabria. Degraded areas still awaiting redefinition on the seafront in the central area not far from the hydrofoil dock. February 2020. Photo Clara Stella Vicari Aversa.



Fig. 4. Reggio Calabria. Sicily with Mount Etna framed by the canopies located on the seafront near the hydrofoil dock. November 2022. Photo Clara Stella Vicari Aversa.

never satiated. We must first of all try to look at this microcosm from and in all directions, trying to continually overturn the point of view, to return to observing the mainland from the sea (as was traditionally done in the passage and crossing between the two shores) but also the sea from the mainland, trying to imagine and interpret, above all, the profound change that is coming, considering the planned stable connection of the Bridge. In a sea basin such as the Strait, in this heterogeneous and permeable strip that has always intercepted different landscapes and architectures, functions and activities, it is necessary to ensure that the arrival of the bridge does not cause a rejection response in the living organism in which it is grafted but, on the contrary, is almost a natural operation, as if the place itself had forcefully requested its insertion. It is a matter of seizing, now, without further delay, the opportunities dictated by future scenarios.

The Strait of Messina area, despite its bubbling with history, myths, legends, seems as if it has been in a state of almost waiting for some 30–40 years; as if it were a 'suspended' or 'blocked' space (even the wait and the constant second thoughts about the bridge [22] have been a strong and evident reason for blockage), as if this place were at a standstill and all around the world was moving. Yet it has always represented one of the nerve centres of the entire Mediterranean, constituting itself over time as an attractive pole and a synonym for crossing. Along its shores there are multiple urban conglomerates and two cities, Messina and Reggio Calabria - actually now three with Villa San Giovanni -, which have long faced each other in an attempt, as yet unsuccessful, to stabilise what is increasingly being seen as the conurbation of the Strait. However, what is lacking to date is a unified vision between the two shores and studies that can act as a glue in the enterprise of considering the area as homogeneous and destined as a whole, with the planned construction of the Strait Bridge, to have a profound effect on the imagination, on its real conformation and beyond. There appears to be an urgent need to redefine a unitary architectural sea front for this precious area, with a response that is as unified as possible and that could also be of an urbanistic dimension, like the extraordinary invention of the *Teatro Marittimo*/*Palazzata* for Messina - the last version of which was reinterpreted and designed by Giuseppe Samonà [23] - in order to outline the three cities together at various scales in a harmonious manner, even while grasping their natural diversity, exposure and specificity (Figs. 5 and 6).



Fig. 5. Messina. View from inside the harbour. December 2022. Photo Clara Stella Vicari Aversa.

It must be understood that this is a great and hardly unrepeatable opportunity for which, if one really wants to aim for benefits, one must overcome particularisms, reasoning as if it were, as in fact it is, a single new large area.

It is thought, therefore, that this approach should be extended to every sphere, e.g. by trying to distribute architecture, urban beaches and marinas taking into account the real needs of a single new large sphere that is growing, perhaps being reborn, in this wonderful crossroads between two seas and two shores.

In order to identify potential and planning, it appears necessary to continuously return to looking both from land and sea, maintaining a constant 360-degree gaze, identifying correct relationships between full and empty, between built and unbuilt, between spaces of permanence and transition.



Fig. 6. Messina. The current *Palazzata* of Giuseppe Samonà at the bottom and the entrance to the city harbour on the right. March 2024. Photo Clara Stella Vicari Aversa.

In the sense that it seems pointless to repeat infrastructures or duplicate them, for example a marina or an urban beach, if not necessary, as if each of these three cities had to claim its own. It is a question of reasoning with a broader vision, at a wider range and at various scales at the same time, with a real desire to intercept, like diviners, the needs of a new single great conurbation of the Strait. There are many works that are already part of the update of the final design of the bridge, the so-called compensatory works, and it is no coincidence that these include the new Straits metro. An infrastructure that symbolically already represents the accomplished expression of the Messina-Reggio-Villa San Giovanni conurbation. And it is certainly a work of great importance and to be given the right planning relevance, almost on a par with the permanent link. Suffice it to say that on the territory of Messina alone, a line (90% underground) of no less than 18.2 km is planned between the area south of Gazzi and that north of Ganzirri-Punta Faro. Impossible, then, especially for planners and architects, not to think that they should commit themselves to the best of their ability and immediately to the prefiguration of a single new metropolitan city made up of several different souls, ensuring that the opportunity and the sea that has always lapped and united them becomes an enrichment for all of them. All three cities of the Strait, albeit in different ways, have always grown up together with the sea, but the relationship with their coastline, unfortunately, has not always been one of symbiosis and enrichment, as can be seen, on the contrary, in other seaside cities. In fact, several stretches of seafront, with the exception of a few overlooks, have for years been closed to the three cities of the Strait, yet it was enough, for example, for Reggio Calabria to bury the railway line to rediscover the magic of a wide seafront reopened to the city's promenade and enjoyment. A process of opening up to the sea is finally taking place in Messina in the area immediately south of the port with the so-called 'via del mare', a process of freeing up the seafront which has already begun in part but which, thanks to the relocation of the railway station and the burying of the railway provided for among the works connected with the bridge, will be able to become truly extraordinary.

This shows that even little would suffice for the three Straits seaside cities, which have exceptional potential that now only needs to be intercepted in order to finally return the sea to the cities.

One only has to look at the coastal cities that have been able to do this as Rio de Janeiro or Miami, but also much smaller and closer to us such as Spain's San Sebastián whose *paseo marítimo* manages to combine in an exemplary manner the use of the

promenade itself as an element defining the coastal space with its pre-eminent urban character [24], and whose Concha beach, was recognized, by *Travellers choice 2024*, as the best urban beach in the world, the third among all beaches in the world. (Fig. 7).



Fig. 7. San Sebastián. Concha Beach, the main public space of the Basque city, full of people all day every day of the year. July 2021. Photo Clara Stella Vicari Aversa.

Seaside cities such as Barcelona or La Coruña, Malaga, or the French city of Nice, owe their good fortune not only to the extraordinary geographical condition in which they are found, but also, and above all, to their ability to maintain over time a real integration between the sea, the beach and the city centre. It is therefore necessary to intervene on the Straits of Messina with a timely operation to reopen and redefine the edges on the sea, returning the beach, possibly with bathing facilities, to the city, as in the above-mentioned sea locations. Doing so can also become an opportunity to implement appropriate regeneration and renaturalisation of places. In the careful, democratic and sustainable use of the urban beach, for example, it is possible to refer to the case of Rio de Janeiro, where not only is the richness of this resource perceived, but there is continuous concern to safeguard and protect it as a precious and primary asset.

The *Instituto- E*, a non-profit organisation dedicated to sustainable development, has been operating here since 2009. Together with *Osklen* (a contemporary brand committed to the philosophy 'As Sustainable As Possible, As Soon As Possible'), it has developed several projects that include, among others in addition to carbon and water footprint monitoring, also and above all the implementation and maintenance of sandbanks thanks to the *Recomposição da vegetação de Restinga fixadora de dunas project in the Área de Proteção Ambiental (APA) da Orla Marìtima* implemented on the beaches of Ipanema, Leblon and Prainha. (Restingas are coastal areas made up of sandy and saline soil, covered with herbaceous and shrubby plants and with a strong marine influence. The fauna is made up of migratory birds, crabs, turtles, as well as mammals such as the caiçara lion tamarin and the otter). A public-private partnership (also involving Janeiro hotels and Airbnb) working jointly with the City of Rio de Janeiro to preserve its flora and fauna by renaturalising its precious beach along the urban waterfront with native species [25] (Figs. 8-9-10).

For the Strait, the sea is the wealth from which to start again, the new place of the project for the relaunch of this new exceptional conurbation, whose planning must immediately abandon particularisms, globalisms, the Italian attitude of dividing into "Guelphs and Ghibellines" but of reasoning all together.

The challenge is important and it is not only between three cities but involves two different regions (a significant challenge but not complex if you think that in Istanbul the bridges connect two different continents) and it is above all a cultural challenge, which can only be implemented by positioning itself exactly in the center of the Strait; So not from the mainland, from one or both shores, but only looking at the shores as a unitary circular front. The centre of the Strait must become the place of the project, engaging not only politics, but also the designers, although it may seem paradoxical.







Figs. 8-9-10. Rio de Janeiro, Ipanema Beach. *Área de Proteção Ambiental (APA) da Orla Marìtima. Recomposição da vegetação de restinga fixadora de dunas.* November 2023. Photo Clara Stella Vicari Aversa.

Just as today it is possible to have new and always different perspectives thanks to drones, in the same way we must change the directions of our project, our own "position" in thinking about the project must find different locations with the same approach in the middle of the Strait.

Of course, a great collaboration is hoped for, we must work in concert between all possible actors, Municipalities, Port System Authorities of the Strait, Universities, in a multidisciplinary and interdisciplinary field, the Region of Sicily and Calabria, etc., to reason and compose together a new architectural and urban piece, just as if it were a new piece of music so that the different instruments, at the various scales, not only do they not clash with each other, but together they reproduce a new architectural symphony. The entire territorial and urban system, the coastal strip and inland areas, must be an

active part of the processes of regeneration and territorial development, in a phase of ecological and digital transition consistent with the technological leap in infrastructure and the innovative support provided by universities.

The Bridge, therefore, cannot be reduced to a parachute infrastructural graft of three thousand three hundred meters, but on the contrary represent the spark to trigger a process of global regeneration of the surroundings, the inestimable opportunity so that finally the entire seafront of the Strait can be rethought and redesigned, enriching itself with all the vital elements necessary for its enhancement and refunctionalization.

The answer must be a unitary redefinition of architectural wings but also of solids and voids that, despite their diversity and variety, can still dialogue with each other, resonating and echoing in this wonderful body of water of the Strait as the protagonist of the entire system; a responsible and contemporary response so that the Strait returns to being in a unitary way that "immense and superb lake covered with boats" already in the past happily identified and outlined by the abbot Saint-Non [26].

Only in this way will we be able to ensure that the dots on the Strait mentioned above do not just join together two by two, tracing single linear routes, but finally sketch and redesign together a new extraordinary architectural and urban framework for the future, framing a precious sphere not only made up of lines and edges, but above all of space and wonderful places of exchange, where one can recharge one's batteries, but above all of being, with the Strait as the main urban square of its new metropolis that is finally coming into being (Fig. 11).

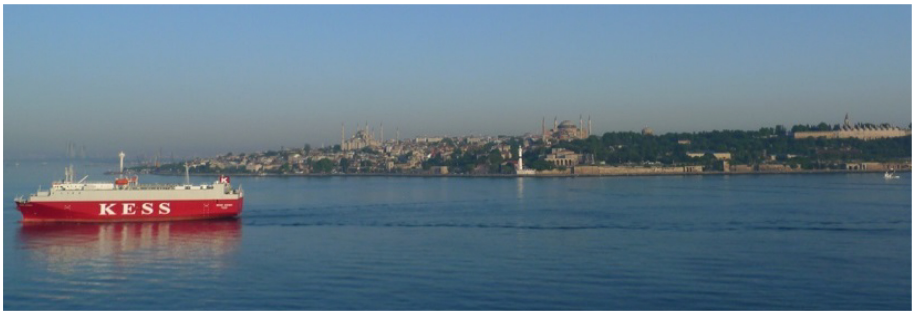

Fig. 11. Istanbul. The Sultanahmet district from the Bosphorus. May 2014. Photo Clara Stella Vicari Aversa.

5 Conclusions

In the territory analysed, there is an overlap of instruments – sectoral, planning at different levels, programming – such as to make the government process difficult, even through the new tools introduced by the most recent regional legislation. There is certainly a lack of a comprehensive plan that identifies the useful tools to ensure adequate integration between the risk framework, the physical framework of priority coastal defence interventions and the institutional framework, which is already quite complex and fragmented.

Although it has a varied morphological conformation and a plurality of landscapes - in which historical coastal settlements alternate, marine urban systems perfectly welded to the infrastructural system, and coasts not yet reached by buildings and wild anthropizations - in the hilly part, despite the numerous building aggressions, different scenic values, areas of environmental value and valuable production areas are preserved. The coast is seen as a boundary, it is connected to its very fractal nature: if the coast cannot be described apart from the spatial and temporal scales of observation, it is also necessary that planning adopts a transcalary approach. The most advanced experiments in the field of environmental planning and coastal planning in general [27], suggest that only some situations and some phenomena can be governed within specific space-time boundaries, while a plurality of problems require transcalary visions, capable of internalizing the externalities produced by the very existence of some boundary, explicitly or implicitly defined. The rules and norms laid down in the plans must therefore apply to portions of the territory and time horizons that change according to the system of relations called into question by the provision itself. It can therefore be said that the lines of intervention to be supported in sensitive territories, strongly affected by anthropic pressure and widespread naturalness - in a mix of man-made landscapes, coastal landscapes, naturalistic landscapes and environmental values - must possess the sense of flexibility of planning moments (in which competing safeguards are able to internalize, with check-lists, transformative processes) and also be aimed at operations that, by graduating the interventions with respect to the different priorities expressed by the ecological-environmental and social components, are aimed at economic revival and:

- to functionally redevelop the coastal areas, enhancing services and activities in line with the lines defined by plans and programmes, comparing them with the load capacities and with the compatibility of use of the interventions in that given territory;
- to promote the homogeneous development of coastal areas, upgrading services and facilities at the service, guaranteeing tour operators the possibility of eco-sustainable investments;
- to ensure the protection of the soil, the protection of natural and environmental components, also with regard to the nourishment of the coast, attention to erosion dynamics, to water quality;
- to enhance the architectural, cultural and archaeological heritage, marine and terrestrial parks, protected reserves, and activities traditionally linked to fishing.

In conclusion, cities in the straits of Europe represent unique urban and architectural contexts, where the boundaries between land and sea merge to create spaces of great charm and complexity. The reflection on these territories makes it possible to explore the potential for development and enhancement of waterfronts, as well as to identify sustainable management strategies that take into account the environmental and landscape specificities of these places and, of course, to know how to combine them wisely [28]. Therefore, Messina, Istanbul and Gibraltar face significant challenges related to the sustainable management of waterfronts, the preservation of historical and environmental heritage and the promotion of balanced and inclusive urban development. Projects for the redevelopment and enhancement of coastal spaces are helping to improve the quality of life of residents and preserve the uniqueness and beauty of the three cities, promoting harmonious and sustainable growth. The analysis of Messina, Istanbul and

Gibraltar offers interesting insights to understand the dynamics that characterize cities in the straits of Europe and to promote sustainable waterfront management strategies in unique and fascinating urban contexts such as these.

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The Recovery of Disused Infrastructure and Military Areas in Spain and Italy, Contributions to the Regeneration of Territories

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Abstract. Brownfields represent complex areas that require appropriate intervention strategies. Now more than ever, the impetus for sustainable land recovery is through the regeneration of sites destroyed and contaminated by conflict or abandoned land conservation activities. These include barracks, forts, defensive and warning installations, former powder magazines, and disused military infrastructure. A forward-looking vision suggests innovative strategies for regeneration.

The essay presented is the result of research conducted on best practices for the regeneration of military areas and is entitled: "Urban regeneration of brownfield sites for future sustainability scenarios."

The essay will present a careful review of the literature and state of the art focusing on best practices in terms of innovative responses useful for ecological transition and resilience of territories.

Through the reconnaissance of legislative and programmatic guidelines and the examination of Spanish and Italian case studies, 3 phases of the regenerative process will be identified:

1. Decontamination;
2. Renaturalization/environmental rebalancing;
3. Refunctionalization.

The essay shows how decontaminated sites will be able to be part of a single environmental and social infrastructure and will have to meet qualitative/quantitative and performance parameters.

Keywords: Brownfields · Redevelopment · Social Justice · Regeneration

1 Introduction

1.1 The Complex Scenario of the Restoration of Decommissioned Military and Infrastructure Areas

The reclamation of disused military and infrastructure areas, while being an environmental priority due to the implications of the abandoned conditions of probably contaminated facilities and installations, often encounters 'resistance' in the planning phase due to the

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complexity of the issues and the financial dimension of any investments required. This is not always due to a lack of attention and adequate policy with respect to critical issues, rather it depends on the difficulty of managing vulnerable territorial areas at environmental risk [1], with large areas in operations that involve local communities, which are often reluctant with respect to the cost-effectiveness of the actions and the externalities produced by the recovery operations.

At present, it is evident that the need to connect the brownfields areas [2] to their surrounding territorial context leads to the choice of a "container" of services and authentic experiences of public interest, such as a landscape garden, multifunctional spaces, with the aim of improving the well-being of citizens and increasing the satisfaction of users and possible tourists.

This mission is not always sufficient to justify and make sustainable brownfields reuse choices and necessary investments. This practice is widespread everywhere, suffice it to say that in Europe, and particularly in Spain and Italy, more brownfields [3] are abandoned than are involved in recovery and regeneration projects.

2 State of the Art on the Rehabilitation of Disused Military and Strategic Infrastructure Areas, Focus on Italy

2.1 Challenges and Opportunities in the Rehabilitation of Disused Military Facilities in Italy: Case Studies and Strategic Considerations

Few reuse operations in Italy have been successful, often they are isolated cases; others are unimplemented projects involving areas of particular historical, landscape and architectural value. Among the former is the project for the D.I.A. [4] in Reggio Calabria, the area is located in the northern part of the city of Reggio Calabria in the Santa Caterina area, near the port and the entrance to the Salerno-Reggio Calabria motorway. The intervention area, located on Via Enotria, is opposite the Manganelli Multifunctional Centre inaugurated in 2014, which houses the offices of the Police Headquarters of Reggio Calabria[1]. Urban context. The parcel subject to intervention is indicated in the P.R.G. tables in zone F called "Areas for military headquarters and equipment", these are areas subject to military jurisdiction.

According to the P.S.C. (piano strutturale comunale-municipal structural plan), the area falls within the A.T.U. (Ambito territoriale unitario - Unified Territorial Area), II.1 of the consolidated urban fabric or in formation, oriented mainly towards the consolidation of the recent city (Fig. 1).

[1] New headquarters of the D.I.A. - Direzione Investigativa Antimafia in Reggio Calabria (RC) (mateng.it).

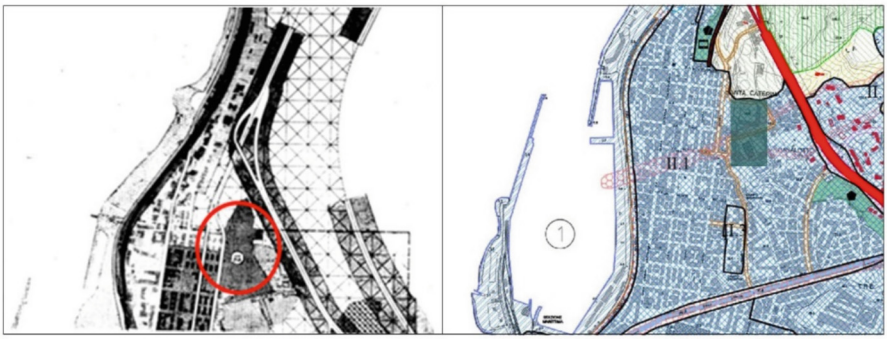

Fig. 1. In the left image P.R.G. 'Quaroni' of 1970, of Reggio Calabria, in the right image Extract of the Municipal Structural Plan of Reggio Calabria, adopted in 2019. Source: elaborated by C. Fazia based on maps of the PRG and PSC of Reggio Calabria.

For the project of the new headquarters DIA, Antimafia Investigative Directorate, several specialized investigations and analyses were carried out: interference analysis with overhead and underground utility networks and design resolution (Fig. 2).

As a result of Law No. 177/2012, about war remnants, which amends and supplements the T.U.S. 81/2008 on occupational safety, the possible definition of a level of risk of non-acceptability implies the need to adopt the necessary prevention and protection measures suitable to eliminate or at least significantly reduce the probability of occurrence of the potentially harmful event. In the latter case, the subsequent conventional securing, defined as "ordnance clearance," can be envisaged, to be activated in the requested case under the aegis and binding opinion of the competent Ministry of Defense pursuant to Art. 22 of Legislative Decree 66/2010 (New Military Code). Therefore, the area affected by the implementation of the DIA, was subject to specific verifications, analyzed in relation to geological characteristics, the presence of possible inhibitory and protective constraints. The presence of possible archaeological finds, seismic risk. The design of the DIA headquarters (it will also host the 12th Mobile Department and the State Police) was drawn up to meet the needs of the Administration receiving the property. At the site of the former military complex now known as DIA, two impressive cisterns that survived the devastation of the 1943 bombings persist. Located in the Montevergine area, specifically in Santa Caterina, these structures, despite their historical importance, have been neglected over the years and are currently in a state of complete abandonment. The two gigantic metal cisterns, with a diameter of about 40 m each and a capacity of about ten million liters, are enclosed by a shell of reinforced concrete and are located within a state-owned area of about ten hectares, now bordered by fences and shrouded in lush vegetation. Originally, there were three of these cisterns, but one of them was dismantled and demolished to make room for the Manganelli multi-purpose complex, the barracks that housed the military personnel responsible for guarding the entire area. What makes this site even more interesting is the presence of a network of vaulted underground routes, still intact, that connected the various cisterns together. This historical heritage represents a fundamental testimony to the wartime events of World War II, so it is essential today to recover and properly enhance it (Fig. 3).

For the new DIA [4] headquarters , the following criteria were met

• Flexibility of spaces and solutions to eliminate architectural barriers, including a tactile path with relative aids in the area open to the public, services and a conference room on the ground floor. The tactile language that will be used is the LOGES-VET-EVOLUTION (LVE) and is created by inserting special tiles into the flooring, the different types of which can be easily felt under the feet and with the white stick.

• Quality of the working environment (systems to improve the quality of acoustics), healthiness of the indoor air and respect for the microclimatic conditions of the site

• Energy saving (photovoltaic system on the roof slab)

• Ease of maintenance and durability of the materials.

The sizing of the building was carried out using the parameter sqm/employee

Total area of intervention: 3,675 m2

Premises: 1.246 m2

Covered area (SC): 985,20 m2

Permeable surface (SP): 1,847.55 m2

Total area (ST): 4,628.92 m

The new building is spread over four floors above ground and a basement for the garage and technical rooms.

On the ground floor, in addition to the archive and the wellness area, there is a conference room. The first and second floors are used as offices and guest quarters. The third floor is dedicated to the manager's apartment. The building is characterized by a central courtyard covered and lit from above with natural light.

The functional layouts, the distribution characteristics and the orientation of the envelope have been designed to improve the energy and functional performance of the building by reducing the consumption of resources and the emission of pollutants. Through:

- controlled mechanical ventilation system with heat recovery;
- primary air diffusion in the room, domestic hot water production systems;
- the draining outdoor pavement plays with the perimeter hedge made of *Teucrium fruticans* and *Phyllirea angustifolia*, an important role in surface water management. The hedge and the portion of lawn that follows the ramp are irrigated with rainwater.

Fig. 2. Sustainability and innovation in the DIA building: architectural and environmental criteria for a modern headquarters. Source: by C. Fazia

Different case is the Former USAF military base. Left to total abandonment, it quickly became a receptacle for trash and debris, as well as an environmental threat due to the massive presence of eternit and rock wool. In the years to follow it has been looted of its still usable removable parts (electrical panels, motors, French doors, sanitary…) [5]. The location is Mount Nardello. We are about 1,750 m above sea level in the territory of the municipality of Roccaforte del Greco. It lies close to Montalto, on a ridge overlooking the Ionian and Tyrrhenian seas, making one grasp the measure of a strategic geographical location. The project that came into being following the 1965 settlement of Americans in Aspromonte, which was never fully realized, is called Aspromont Horizon. It is the name of the study that, since the late 1950s, the United States has been processing, with bases in Catania and Trapani, as a strategic crossroads in the area of sensitive data collection and processing. Abandoned in the late 1980s, it was officially decommissioned in 1993 and transferred to the Italian Ministry of Defense, falling into a total state of disrepair [6]. The base was reactivated on May 10, 2023 for some military exercises, the Municipality



Fig.3. Aerial photo of the metal cisterns in Santa Caterina, Reggio Calabria. Source: https://www.citynow.it/reggio-e-le-antiche-cisterne-nascoste-uniche-sopravvissute-alle-bombe-del-1943/

of Roccaforte, by resolution of the Regional Council of Calabria, acquires the entire territorial jurisdiction over the former military base of Monte Nardello in 2019; the former military facility fell almost entirely within the Municipality of Roccaforte del Greco, with the exception of 200 m^2 (the entrance to the former radio station) falling within the Municipality of Reggio Calabria. With the administrative aspects clarified, the conditions can be created to boost redevelopment and enhancement projects for the area.

The Monte Cimone Barracks in Banne is located in a predominantly agricultural area, is connected with provincial roads that connect the capital with the Fernetti-Sesana pass, where there is an interport, an infrastructure dedicated to intermodal logistics. Its location is strategic, for the Adriatic and the Mediterranean. It is in close proximity to a connecting hub for freight traffic between Central and Eastern European markets and the Mediterranean basin. A few kilometers away is the Area Science Park, which operates the Trieste Multi-Sector Science and Technology Park. The complex has 28 main buildings, 5 of which have been declared of cultural interest, as well as a number of small accessory buildings with their appurtenant areas covering an area of more than 17 hectares (Fig. 4).

Despite the many solicitations and ideas, including those initiated by local administrators, for the environmental rehabilitation and social use of the area of the former Monte Cimone Barracks in Banne (formerly the Bidischini-Burgstaller Estate) and recovery for use by the community, the reuse of the largest of the abandoned sites in the territory of Trieste is quite complex. The State Property Agency has been trying to manage the decommissioned military assets, with the aim of triggering multi-level urban regeneration and redevelopment processes [7] through a coordinated system of interventions and partnerships. But even the mere enhancement of an important part of the public heritage, with benefits from public use at least in its forested part, becomes quite complex. The possibility of accessing the funding opportunities of the regional programming of



Fig.4. Banne barracks, source: Journey to the dilapidated former barracks of Banne, candidate to become a CPR PHOTOS - Il Piccolo (gelocal.it)

the European Structural and Investment Funds 2021 - 2027 remains open. The European Regional Development Fund 2021 - 2027 (ERDF ROP 2021–2027), which provides funding for "territorial regeneration projects" for the "enhancement of some of the region's iconic places," is an opportunity to be seized. To this end, many administrators urge "territorial regeneration interventions" that can activate local resources by involving communities. The Mardichi area [7], also known as the former Artillery Barracks, is an architectural complex of great historical importance to the city of La Spezia. In the past, it housed the headquarters of the Army Cavalry and later the Navy Artillery. This area had a defensive function of the arsenal and represented a true independent citadel capable of resisting even a siege [8].

The State Property Agency has commissioned a detailed survey campaign to assess both the seismic vulnerability of the existing buildings and the presence of polluting materials in the complex. In the meantime, a fruitful collaboration has been initiated with the Superintendency to strike a balance between conservation and innovation. The project involves the rehabilitation and restoration of three out of four buildings. The central building, which has undergone several alterations over time, including as a result of bombing, will be demolished and rebuilt to house the new offices of the Internal Revenue Service, while the other two buildings will be consolidated and house ancillary functions such as archives and a conference room. Special attention has been paid to the ruined building, which once consolidated will be enhanced as a historical memory within a public park open to citizens. A new wooden floor will be built in the center of this attractive space, which will allow for the holding of events, concerts, and demonstrations, as happened sporadically in the past on the premises of the Barracks. In this way, an urban area that is currently abandoned and has been the subject of occupations will be redeveloped, returning to the citizenry, which has publicly requested it several times, a venue for an important institution and a park usable for all.

The project, following the practice of the Agenzia del Demanio (D.R. Liguria) will be carried out in accordance with Leed sustainability protocols, and the offices will be designed with advanced structures adapted to recent innovations in SmartOffice. The former seaport with the Nervi warehouses and the former ammunition depot at Via

Dante Alighieri, Marsala (Trapani), disused since the end of World War II, its facilities are still military area owned by the Italian Air Force, sporadically the facility is used for amphibious military aircraft. Regarding the former ammunition depot on Via D. Alighieri, it would appear that the area was reclaimed several years ago and secured with a metal boundary placed around the perimeter. The area is in a state of neglect.

There have been attempts at reclamation, which have remained unimplemented. An agreement had been made with the Ministry of Defense according to which, the area of the Nervi hangars could be acquired free of charge by the City of Marsala, if it undertook to change the use of the area of the former ammunition depot, up to the Marsala ring road. The area would have remained at the disposal of the Defense, but with a new zoning destination; the former military seaport in contrada Giunchi, on the other hand, would have been ceded free of charge to the same administration. For the Former Military Hospital, located in Corso Calatafimi in Palermo, urban redevelopment works were started in November 2020 that will lead to the refunctionalization and restoration of the former military hospital, now abandoned for about 18 years, within the Michele Ferrara barracks in Corso Calatafimi. The former military facility will be repurposed as a new Carabinieri Headquarters Hub where a few departments and warehouses that are now located in different locations will also find space. The work, worth 7.2 million euros, was financed by the State Property Agency and the Region of Sicily.

3 Significant Materials and Methods of the Case Studies. Decommissioned Military Infrastructures in Spain: Ideas and Projects for Their Redevelopment

3.1 La Real Fábrica De Armas De Orbaizeta (Navarra, Spain) as an Engine for Local Revitalization

As a result of numerous international geographic and governmental changes following triggering events that have led to shifting economic, social, and political interests many facilities and infrastructures intended for military functions have become obsolete or even unsuccessful.

The European scenario is dotted with so called “Military Voids,” some more recent others older [9]. An example would be the former “Real Fábrica de Armas y Municiones de Orbaizeta”. Its history and nature give it a double role in its categorization.

In fact, this structure can be counted not only as a “military vacuum,” but also as a splendid example of industrial archaeology. Its history begins in the 18th century located in the valley of Aezkoa, 5 km from the border with France, in the heart of the Pyrenees. The ruins of the former arms factory are a reminder that hidden in the Irati forest was born the main military-industrial center of Northern Spain. Its strategic location gave it easy access to excellent raw materials (iron, water, and wood), making it a very productive establishment, but its proximity to the border with France also made it an attractive place for fires, looting and raids. The development of this complex is divided into two main phases: the first running from 1785–1789 and the second from 1789–1794. This era was marked by many vicissitudes such as the wars against France and the Carlist Wars, which is why the Royal Arms Factory arose; its purpose was to supply the army with arms and

ammunition. The factory suffered numerous attacks during the wars, the various fires and raids caused it to be abandoned in 1884. The factory was an important industrial center during the 18th century. It employed more than 2,000 workers and produced a wide range of weapons, including pistols, rifles, cannons and grenades. Today, the factory ruins are an important historical monument.

They are considered a testament to the importance of the industry in Navarre's history. Archaeological excavations conducted in the Royal Arms Factory of Orbaizeta have revealed important information about the history and operation of the factory. The complex boasts some rather innovative techniques such as, for example, the underground channels that carried water from the dam to the machinery [10]. With its 100 years of operation marked by multiple vicissitudes, the facility played a key role in supplying the army during numerous war campaigns, the fascinating structures that remain today are an indelible sign and memory of the history of the place. Although the industrial complex has been classified as an asset of cultural interest, its state of neglect, caused by the inactivity of the infrastructure dedicated to industrial production, placed it among the architectures at risk. The economic recession resulting from the abandonment of industries characteristic of the area under consideration and the increase in urbanization have prompted the consideration of abandoned industrial and military heritage as a tool for the revival and revitalization of the area. For this reason, The Royal Orbaizeta Ammunition Factory has been considered an excellent engine for the revitalization of the local economy [11]. The complex and the surrounding areas have always been a source of interest for scholars and archaeologists; in fact, numerous archaeological campaigns were carried out in the late 1980s and early 1990s. The curiosity and involvement that arose over time for this place meant that funds were allocated for its revival. The redevelopment project sees the factory as the centerpiece for a broader process of reactivation of the entire area that focuses on a new economic viability and a more sustainable vision of the management of the place. The project integrates visitor accommodations while fully respecting the original architecture. Between 2018 and 2020, work was promoted on the reconstruction of the building that housed the furnace, considered the "heart" of the large industrial/military complex. This has promoted not only free visitor access to the facilities, but also other cascading interventions related to the reactivation of dormant structures. One such initiative is the visitor reception center called "Kultur Ola" opened in 2023. The old weapons factory building has been reopened and renamed "Aezkoako Kultur Ola," this cultural project at the entrance to the Irati Forest represents an exhibition space that showcases the historical and cultural heritage of the place and its community. The creation of this new association space not only allows a site of historical interest to be reopened to the public, but also provides an opportunity to share the heritage with the local community and visitors, further enriching an already intrinsically valuable place.

The Royal Munitions Factory in Orbaizeta is renewed, becoming an attractive tourist destination and, above all, an engine for the revitalization of the local economy, demonstrating how abandoned industrial and military heritage, if properly enhanced, can be a catalyst for the rebirth of an area (Table 1).

Table 1. Analysis of the framework of the case study "Real Fábrica De Armas De Orbaizeta" (Navarra, Spain).

Region:	Navarra
City:	Orbaizeta
Name:	Real Fábrica de Armas de Orbaizeta
Initial destination:	The area was created for military and industrial purposes. It played a key role in supplying the Spanish army with weapons and ammunition during periods of war, such as the wars against France and the Carlist wars
Age of construction:	Built by order of Charles III of Spain in 1784, it remained operational until 1884
Dimensions (range): < 1000 mq > 1001 e < 10.000 > 10.001 mq	< 10.000
Relationship with the urbanised context: Interior Exterior near urban areas Exterior in suburban areas	The area of the former Orbaizeta weapons factory is located far from urban centres, within the Irati forest its proximity to the French border favoured sieges and raids
State of disuse: Abandoned Underused	Despite its status as a cultural asset, the complex has long been regarded as a structure at risk due to its state of neglect
Conversion implemented or in progress:	The redevelopment project, which saw the reconstruction of the bakery building and the opening of "Aezkoako Kultur Ola" in 2023, represents a significant breakthrough
Mixite with prevalence of:	The new association/reception space not only allows the site to reopen to the public, but also promotes the sharing of heritage with the community and visitors, contributing to local economic revitalisation
Monofunctional:	No
Environmental criticalities and vulnerabilities of the study area and context:	Increased tourism in the area in question could compromise the ecological value of the nearby Irati Forest, endangering biodiversity and the integrity of the natural habitat
Contaminated site:	No

(*continued*)

Table 1. (*continued*)

Widespread urban decay:	No
Management complexity:	An increase in tourism in the area requires careful management to preserve the ecosystem. The design and management of roads, tourist facilities and other infrastructure must be oriented towards sustainability in order to prevent harmful impacts on the forest and surrounding natural areas

3.2 Regeneration Process of the Case Study of the Disused Military Area of Gefate (Madrid, Spain)

The decommissioned military area of Getafe, located in the autonomous community of Madrid, is a significant example of the regeneration of a former military area. This air base, which was once of strategic importance to the Spanish Air Force, was decommissioned in 1996, leaving a disused and unused area [12]. The decision to regenerate the Getafe military area was motivated by several factors. First, the decommissioning of the air base left a void in the local community in terms of employment and economic development. In addition, the decommissioned area was an environmental problem, with the need to address decontamination and redevelopment of the land. Finally, the regeneration of the area was seen as an opportunity to promote sustainable development and improve the quality of life for the local community [13]. The regeneration process of the Getafe military area was guided by a forward-looking vision that embraced innovative strategies for the transformation of the area. The process was divided into several phases, including decontamination, denaturalization/environmental rebalancing, and refunctionalization [14].

The first phase of the regeneration process was decontamination of the area. Extensive investigations were conducted to identify and manage the presence of residual toxic materials and substances from past military activities. Measures were taken to clean up and dispose of contaminated materials in accordance with current environmental regulations. This phase was critical to ensure that the area was safe for reuse.

The second phase of the regeneration process focused on denaturalization and environmental rebalancing of the area. Actions were implemented to restore biodiversity and ecological balance, such as creating green areas, reintroducing native plant species, and promoting habitats for local wildlife. Sustainable management systems for water resources and green areas have been adopted, thus contributing to improving the environmental quality of the area. Subsequently, the focus was on the refunctionalization of the area. Strategies were developed to redevelop existing facilities and create new spaces for different purposes. The Getafe military area was transformed into a multipurpose center, housing not only residential, commercial, and recreational activities, but also spaces for education and research. Pedestrian and bicycle paths have been created to promote sustainable mobility within the regenerated area.

This regeneration has had a significant impact on the local community and the surrounding environment. The area has become a hub for sustainable development and quality of life, contributing to job creation and promoting environmental sustainability. In addition, this regeneration has transformed the area into a meeting and exchange place for the local community, improving social cohesion and quality of life [15].

The case study of the Getafe military area provides several lessons learned and best practices for the regeneration of disused military areas. First, it is crucial to have a forward looking and integrated vision that considers economic, social, and environmental aspects. In addition, collaboration between public, private, and local community entities is essential to the success of the regeneration process. Finally, environmental sustainability and the promotion of quality of life must be at the heart of regeneration strategies (Table 2) (Fig. 5).

Table 2. Analysis of the case study of the former Getafe air base (Madrid, Spain).

Region:	Madrid
City:	Getafe
Name:	Ex military area of Getafe
Initial destination:	The area was originally intended for military purposes, used as an airbase and training centre for the armed forces
Age of construction:	1950s–1960s
Dimensions (range): < 1000 mq > 1001 e < 10.000 > 10.001 mq	> 1001 e < 10.000
Relationship with the urbanised context: Interior Exterior near urban areas Exterior in suburban areas	Southern suburbs of Madrid. The military area of Getafe is located within the urban context of Getafe, a city on the southern outskirts of Madrid
State of disuse: Abandoned Underused	Abandoned. The military area of Getafe was decommissioned by the Spanish armed forces
Conversion implemented or in progress:	Undergoing reconversion to be reused for civil purposes
Mixite with prevalence of:	Creating a functional and dynamic urban space offering services and opportunities for the local community
Monofunctional:	No
Environmental criticalities and vulnerabilities of the study area and context:	No environmental criticalities or vulnerabilities of the Getafe military area or its surroundings are specified

(*continued*)

Table 2. (*continued*)

Contaminated site:	No
Widespread urban decay:	Urban decay following its decommissioning, lack of maintenance and transition from military to civil use
Management complexity:	The management of the former military area of Getafe can be complex due to the size and characteristics of the area. It requires careful planning and management to ensure optimal use of the area and maximise benefits for the local community

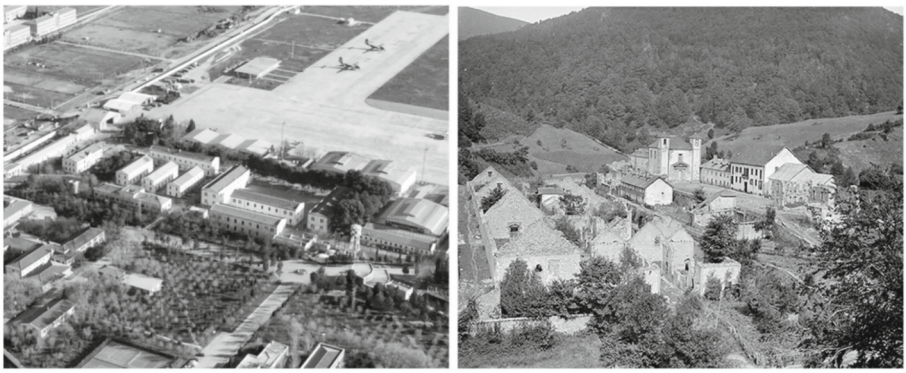

Fig. 5. Left image: Aerial view of the former military area of Getafe, Spain. Source: https://ejercitodelaire.dfensa.gob.es/EA/centenariobasesaereas/getafe/multimedia.html. Right image: Aerial view of the "Real Fábrica De Armas De Orbaizeta", Spain. Source: https://nabarralde.eus/la-real-fabrica-de-municiones-de-orbaizeta/

4 Conclusions

4.1 Strategies and Opportunities for the Sustainable Redevelopment of Disused Military Sites[2]

The issue of rehabilitating brownfield sites, considered as fragments that make up the urban fabric, has been the subject of extensive debate in the urban planning field until the late 1990s. However, with the process of "de-demanization" of military sites, attention

[2] Research carried out as part of the activities of the "SS_Consumption Convention. Stop soil consumption: between reuse and regeneration" coordinated by Celestina Fazia as Scientific Responsible and Coordinator of the activities related to urban, territorial and landscape planning in relation to soil consumption, urban strategies for reuse and regeneration of land, also with reference to case studies of international level. Members of the research group are: Giulia F.G. Catania, Federica Sortino.

has also shifted to provincial realities, where military voids appear as real "micro-cities". Reclaiming these areas requires innovation and sustainability, as it often means doubling the space available to local communities, changing the balance and dynamics existents [16]. As of today, for example, the Banne site is disused, the large size of the areas and parts of which it is composed make initiatives and proposals for the recovery and enhancement of the entire area particularly challenging in terms of economic feasibility. In this context, Sara Carciotti's (2021) article [17, 18] proposes new networked governance tools that activate urban regeneration as a key lever to counter land degradation and promote a social and economic project that includes different settlement, environmental, landscape, institutional and participatory dimensions. The strategic location of the area, at the center of a territorial system (Italy-Slovenia-Austria-Croatia) favorable to the union of different cultures, represents an opportunity for experimentation to be included in Friuli-Venezia Giulia's regional plan for the use of European funds 2021–2027, which provides for the funding of territorial regeneration projects proposed by municipalities. The adoption of the network paradigm and the collaborative approach among different stakeholders are key to addressing the complexity and dynamism of a problem such as the redevelopment of a portion of a city. It is important to consider the entire territorial network and involve all stakeholders.

The proposal is based on viewing the city as a complex system involving economic, social, environmental, spatial and architectural aspects. It also promotes open networks for experimentation and innovation, taking into account possible external shocks. It is essential to involve local people, who have historical knowledge and contemporary needs related to the area in question, as well as urban planning at different levels. This involvement makes it possible to create an integrated plan that overcomes the divisions and walls that have demarcated the area over the years. The goal is to create new connections and foster collaboration among all stakeholders in order to achieve a sustainable and inclusive redevelopment of the former Banne Barracks. For the former Mardichi Barracks. La Spezia, the collaboration with the Superintendence for balancing conservation and innovation is an important step to ensure respect for the historical and architectural heritage. The rehabilitation and restoration of three buildings within the complex, along with the demolition and reconstruction of the central building to house the new offices of the Internal Revenue Service, will help breathe new life into this urban area. The creation of a public park open to citizens, with new wooden flooring for events and demonstrations, will help revitalize the area and make it usable for all.

The project will be in line with sustainability protocols such as LEED or similar, which focus on energy efficiency and the use of sustainable materials. The BIM approach will ensure efficient management of all phases of the project. In addition, the focus on office adaptability to current trends such as the smart office is very relevant as well as innovative, especially considering the needs that may emerge in the post-pandemic era. In the former maritime port of Trapani, the projects hypothesized for the recovery of the area are various: from the possibility of transforming it into a school or a sports citadel, to the possibility of converting it, changing its intended use, to create hotel facilities for new employment outlets, but also the proposal to build a scientific pole.

There are many interesting proposals and solutions[3] [19], but the complexity of the site, related to environmental dimensions, urban planning issues and the cost of the intervention, does not encourage the implementation of even partial regeneration projects.

The redevelopment of military spaces can be a contribution to the "overall redevelopment of the neighborhood and a sign of the important results that are achieved through collaboration between institutions," as in the case of the former Palermo hospital. It will be an opportunity to redevelop the Corso Calatafimi area (which has widespread urban decay and numerous abandoned artifacts that significantly reduce expectations for development and social growth) and to raise service delivery levels for the benefit of the entire community. The analysis of the reactivation of the Industrial/Military Heritage of the Royal Orbaitzeta Arms and Ammunition Factory allows us to understand how redevelopment interventions in these areas operate on two levels: a physical one and a theoretical one. There is a fruitful interpenetration between the ability to create productive landscapes within cultural environments capable of bringing the architectural identity of the specific place into dialogue with the broader sphere of historical and cultural heritage, allowing for an investment that is not only commercially profitable, but also socially rewarding. The case study of the Getafe military area provides several lessons learned and best practices for the regeneration of disused military areas. First, it is essential to have a comprehensive vision that considers economic, social and environmental aspects. In addition, collaboration between public, private, and local community entities is essential to the success of the regeneration process. Finally, environmental sustainability and the promotion of quality of life must be at the center of regeneration strategies.

Several issues related to the costs/investments for transition contribute to the "redesign" by obtaining as a result indicator the achievement of 5 objectives:

- overcoming the territorial and social gap;
- job creation;
- the multi-temporal and multi-spatial strategy (strategy of tangible and intangible networks);
- the use of operational tools for urban, territorial and social regeneration;
- the promotion of policies for proximity.

These aim to modify urban development so that services are accessible in less than 15 min (Carlos Moreno), It will be necessary to introduce, at the urban scale, criteria for

[3] Andrea Rizzardini's Twin Hangar project proposes: Coastal Cultural Park. The park takes advantage of the landscape and environmental heritage to enhance the area's territory consisting of the typical landscapes of the coastal area washed by the Stagnone lagoon, salt marshes, and typical Mediterranean scrub. Sports and educational activities. The structures of the former seaplane base will be partly demolished and partly restored; the Nervi hangars, like a monument, will be the relics of modern architecture, housing new functions. Connections - The landings at the new cultural sports center mean that the area can be reached by: car; bus; rail (the passage of the Palermo-Mazara del Vallo railroad next to the former seaplane base makes it possible to insert a stop, paying close attention to the connection with Trapani, from which it is possible to embark for the Egadi Islands, Africa or Sardinia).

the preservation of the natural structure of places, vegetation patterns, the surface hydrographic system and its ecological structures and ecosystem services. In order to strike a good balance between sustainable development and the abatement of land consumption, we need to abandon the expansionist policies and strategies that guided 20th century planning and redirect our interest to the abandoned areas of the city. The repurposing of "urban voids", such as disused military areas, can ensure multiple benefits in this regard. We need to consider disused military assets as a system composed of variable-geometry citizenship networks, knowledge networks, ecological and environmental networks, cultural heritage, tourism offerings, and infrastructure systems.

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A Valuable Brownfield Site by the Sea Awaiting Regeneration: The Case of the Lipari Pumice Quarries

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Abstract. The history of pumice and obsidian extraction has ancient roots and identity for the island of Lipari, representing an activitỳ of great value, to be protected and promoted. The largest of the Aeolian islands has had a long industrial history based on the extraction of pumice stone, dating from the Neolithic, present in very pure quality thanks to the island's volcanism.

Pumice has always characterised the island, attracting applications for monopoly concessions from various companies in the late 1800s and early 1900s. In 1958, the company *Pumex S.p.A.* was founded, which in just a few years managed to incorporate and purchase almost all the pumice lots. In 2000, the Aeolian volcanic archipelago became a UNESCO World Cultural Heritage Site, representing an important model for the study of volcanology worldwide. *Pumex* was declared bankrupt and is still under the control of the bankruptcy court. Thus, in addition to the quarries, *Pumex*'s buildings have also been abandoned, risking the disappearance of all physical evidence of the pumice quarry and the industrial architecture functional to them that, long before tourism, made the island of Lipari prosperous. In 2021, the Sicilian Region had announced the acquisition of the area for the establishment of a geo-mineral park and the creation of a Museum of Pumice Stone Processing. But the area is still waiting. Attention must be kept alive and a regeneration project initiated so that the island's ancient heritage of pumice and obsidian mining is not dispersed but properly protected and enhanced.

Keywords: Seafront regeneration · Brownfield regeneration · Lipari pumice quarries · Disused industrial landscapes by the sea · Regeneration and Architecture

1 Introduction. Disused Industrial Landscapes by the Sea: The Special Case of the Lipari Pumice Quarries

The volcanic landscape that characterises all the Aeolian islands, in the case of Lipari, the largest of the seven, is also inextricably linked with its extraordinary mineral wealth of pumice and obsidian. Wealth that has been the reason for the anthropisation, as well as the mining exploitation of these volcanic territories, since antiquity, also representing something of strong identity for the same, of which the quarries represent the most obvious epilogue.

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Mining activity was interrupted several years ago and the disused pumice deposits are still awaiting their redefinition and a suitable regeneration project.

Yet this long wait seems like a great missed opportunity, as it now seems to have been accepted that "having lost their original function, disused industrial buildings and areas constitute a strategic factor in the process of reinterpreting parts of the city, responding to the demand for new spaces and functions above all through the recognition of their identity and cultural value as a lever of quality and competitiveness in support of possible development" [1].

The abandonment of mining activity, therefore, does not seem to have brought any benefit, unfortunately, for the island and for the landscape setting by the sea, albeit a splendid one, in which the former pumice quarries stand like precious gems set.

Usually, the presence of quarry sites has a more or less profound impact on the landscape and the context on which they insist, and the phenomenon of their decommissioning is almost always an ameliorative choice for the sites themselves. And this is the case whether the extractive sites are located in natural or urban contexts, although it is certainly in the latter that environmental, but also social, degradation, if left unchecked, becomes more evident.

Disused quarries, wherever they are located, always leave deep wounds and lacerations, even more so if they are situated on the banks of water, rivers, lakes or the sea, as in the case of Lipari, and can also represent a significant environmental and landscape problem, as they can become hotbeds of pollution or, in some cases, even real illegal dumps.

Faced with disused quarry sites, it is therefore clear that timely intervention and plans for their regeneration are desirable, naturally assessing the adoption of more appropriate measures on a case-by-case basis, but in any case, attempting to intervene as soon as possible to avoid further deterioration of the landscape. And so, depending on the case, action can be taken, for example, to reclaim these now-empty areas of the quarry sites, to restore their natural conditions, to regenerate and redevelop the areas themselves, to introduce different and new functions, perhaps by creating recreational activities, parks, meeting spaces, museum sites, etc.

The case of the disused quarries on Lipari, in this framework, appears particular and anomalous.

In fact, generally speaking, disused quarries are quarries that are no longer used for the extraction of materials, such as stone, sand or other materials, because the quarry itself has now exhausted its resources or it is no longer economically viable to continue its extraction or activity. It is, therefore, for one or both of these reasons that they are closed or abandoned.

In the case of Lipari, this was not the case at all. In fact, at the time when quarrying ceased, the quarries had by no means exhausted their resources, on the contrary; and moreover, production was not at all economically inconvenient, rather the opposite was true. Nor did the area appear degraded from a landscape point of view, despite the continuous excavations that caused the waste, i.e. the pumice dust itself, to flow into the sea. Indeed, during the long period of excavations, the sea was an even more vibrant blue than it appears today, as the very fine powder of pumice deposited on the white seabed made the white architectural and scenic beauty of the surroundings stand out,

shine and reverberate even more. Now on the mountains of pumice, due to the stop of excavations, vegetation has grown and the landscape is less 'unique', and therefore also the reflections of the vegetation tend to a sea that is still blue but 'greener', less celestial but above all also less peculiar than how it appeared before.

Yet these particular white mountains sloping down to the sea "are a heritage recognised by UNESCO, linked to mythology, that must not be erased. Curzio Malaparte, whom fascism sent into exile on Lipari, wrote about them… Erasing the memory would be offensive" [2] and it is on these that urgent work should be done to regenerate the entire area with an operation of restoration and architectural, landscape, cultural, social and anthropological regeneration. (Fig. 1).

All in keeping with what is now recognised, namely that whatever approach to the regeneration theme and whatever strategies are adopted, the common goal must be to restore identity to those areas whose content has been distorted by the cessation of activities.

2 A Precious Former Industrial Area by the Sea on Lipari Awaiting Regeneration

In order to better understand what this precious area on the sea with a great identity value represents, not only for Lipari, the largest of the Aeolian islands that had fascinated Dumas, Maupassant and Carducci among others, but at least for all the seven 'sisters', it is worthwhile to make a historical summary of what these same mountains have experienced.



Fig. 1. Views of the Pietra Liscia and Porticello area, with Panarea and Stromboli in the background, during a joint inspection with the bankruptcy trustee and representatives of the Messina *Ordine degli Architetti*, the *Fondazione Architetti del Mediterraneo* of Messina, the *Istituto Nazionale di Bioarchitettura* and the *Ministero della Cultura*. July 2021. Photo Clara Stella Vicari Aversa.

The pumice mountains, in fact, have an infinite number of stories to tell, and yet we often "continually speak of the centuries that preceded ours or of those that will follow

it, as if they were totally foreign to us," as Marguerite Yourcenar wrote in her 'Memoirs of Hadrian', adding: "I touch them, however, in my stone games: the walls I prop up are still warm with the contact of bodies that have disappeared; hands that do not yet exist caress the shafts of these columns…" [3].

The history of pumice and obsidian extraction has ancient roots and identity for the island of Lipari, representing an activity of great value, to be protected and promoted.

The former, a light porous material, was mainly used as a building material, the latter, a dark vitreous material, hard and sharp, was used to make weapons and tools. Obsidian and pumice, still present today on the north-eastern side of the island, are the result of the last eruptions of Mount Pilato, with pumice deposits covering 8.4 square kilometres, about 22% of the entire island of Lipari, along the eastern and northern coastline between the hamlets of Canneto and Acquacalda, which were formed by the first conspicuous pumice excavations around the end of the 16th century. A.D. But the use of pumice stone in the largest of the Aeolian islands certainly has more distant roots, with a long industrial history based on the extraction of the same, present in very pure quality thanks to the volcanism of the island, dating back as far as the Neolithic period, around 4000 B.C., with the first settlements on the islands of Lipari and Salina [4].

The extraction and trade of this volcanic stone was first formally recorded on 18 May 1276, when King Charles of Anjou is said to have authorised the Bishop of Lipari, who had been lord of the Aeolian Islands since the time of the Norman domination, to export and trade pumice stone in addition to sulphur and alum.

Estimates of quarrying in those early years of trade are around 100–200 tonnes per year, with pumice from Lipari expanding unrestrainedly in Europe, both for cosmetics and construction to the extent that it was used in the construction of the hemispherical dome of the Chapel of Santa Maria del Fiore in Florence. It even seems that pumice was already so famous that it was cited by Vitruvius as an interesting conglomerate lighter than water and even used in the construction of the dome of the Pantheon in Rome in 120 AD. The natural resource extracted on Lipari appears to have been in such high demand and so well known that in the centuries following the Middle Ages it even interested international scientists.

Déodat de Dolomieu described Lipari in 1781 as "the immense storehouse that supplies pumice to all of Europe… The whole island seems to have this truly extraordinary substance as a base" [5].

Initially, from 1200 to 1800, the quarrymen, individually or in family groups, organised themselves autonomously by selling the extract to the captains of the sailing ships that landed on the island, but the activity could not cover the immense demand that came from Italy and abroad, and so with the industrial revolution, extraction became increasingly dedicated to entrepreneurs and their companies.

Pumice mining was carried out in an industrial form from the 18th century onwards, also attracting several requests for monopoly concessions from various companies around 1880, when they settled on the island, first to purchase the product, then implanting the first mills in Canneto, Acquacalda, and Porticello for grinding to different sizes, and finally purchasing pumice land from private individuals.

Over the years, there were several companies and prominent figures such as Francesco La Cava who, instead of becoming a sea captain as in the family tradition,

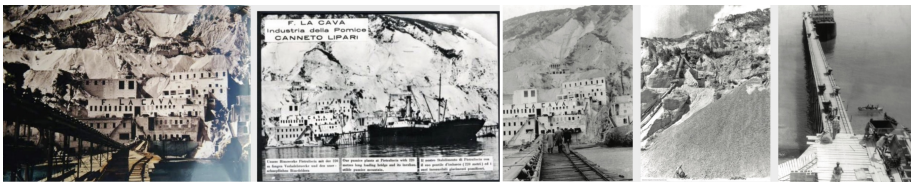

Fig. 2. Photos and postcards found by Clara Stella Vicari Aversa in the rich private archive of Antonietta Liotta Papocchia, niece and heir of Francesco La Cava.

found himself captaining a pumice industry, arriving almost by chance in the mining sector and achieving prestigious positions abroad. La Cava also realised that in order to survive, the pumice industry had to be competitive in the various markets of the world and that it was therefore necessary to modernise, reducing production costs and resorting to new technologies. Thus, the extraction of pumice stone and all subsequent production steps, outside and inside the factories, were gradually modernised and automated. Conveyor belts were thus installed on the wharves, considerably reducing the port labour force: an increase in production, with automated systems throughout the whole chain and reduced production costs, that would expand the sales markets, ensuring more work for the Aeolians. The results intuited by La Cava were not long in coming and the small cabotage ships of 100–200 tonnes were soon joined by ships of 10,000–20,000 tonnes, making it possible to conquer and reach new markets that were previously unthinkable, from Africa to Northern Europe. And since in the meantime the local industry was equipping itself with increasingly sophisticated wharves and machinery, ships of even larger tonnage landed on Lipari, enabling pumice from the Aeolian Islands to be introduced, as an alternative to pumice from Greece and other countries (it seems, moreover, that pumice from Lipari is the best in existence thanks to its high silica content, extraordinary porosity and lightness, combined with mechanical strength), even in the distant markets of the United States of America. The employment of harbour labourers also had a satisfying counterpart in both quantity of work and far less physical performance, enabling a time of great growth and demand for pumice for industry and the local economy. With the industrialisation of the processes, after the 1950s, the pumice workers themselves began to perform more human tasks (relieving them of the heaviest actions and above all reducing the risk of silicosis thanks to the introduction of cylindrical rotary kilns that no longer exposed workers to the inhalation of dust in its anhydrous state) but it did not change the production process which, in fact, in both the pre- and post-machine periods, is essentially divided into: excavation, screening, drying, milling, packing, boarding. There were, in fact, unfortunately not a few recognised cases of silicosis throughout Lipari. La Cava himself was involved, but he also managed to fight, winning his battle, so that the occupational disease of workers in all dust-based extractive industries would no longer be referred to by the term ‘liparosis’, as the scientific community was proposing, almost as if he wanted to brand the island of Lipari among so many other mining realities, but with the more generic term ‘silicosis’. [6]. (Fig. 2).

In an April 1961 report published in the daily newspaper ‘La Stampa’, journalist Francesco Rosso described the quarries as follows: “The entire northern side of the island of Lipari is an immense pumice quarry, part opencast and part furrowed by hundreds

of narrow tunnels. A thousand workers work there. On windy days, a compact white cloud of insidious dust envelops the mountainside. The workers have to leave their jobs: a day without wages in the narrow budget of a year's toil that is poorly repaid. In the summer months, when the sun blazes relentlessly, working up there is frightening. The rock releases an intolerable heat, the scorching dust suffocates, the thirst tortures and the less strong yield" [7].

Around 1950, the parcelling out of the quarries had led to the creation of more than forty quarries, putting the sector in crisis due to excessive competition between them, as more than twenty companies, ranging from individual ones to groups of large industrialists, were engaged in pumice pickaxing. In 1958, the company *Pumex S.p.A.* was founded, which from 1968 managed to gradually incorporate and acquire other pumice extraction activities, initially leaving only three competitors active: Francesco La Cava's company in Porticello, Italpomice in Acquacalda and the S. Cristoforo Cooperative in Canneto, which only dealt with the production sector and continued its activities until the second half of the 1980s, when, to the sound of acquisitions, *Pumex*'s monopoly on pumice on Lipari was, if not legally (in the meantime La Cava had fallen victim to silicosis), then de facto. (Fig. 3).

The testimony of all these 'cascading buildings, incorporated into the natural landscape' that insinuate themselves into the white pumice mountains and their relative tracks, the spaces between architecture and pre-existing structures, the jetties, is still spectacular today, being able to "re-read the abandoned industrial spaces of the former factories of Th. Ferlazzo and F. La Cava" [8].

"To the disappearing proto-industrial quarry landscape, the architectural artefacts of the period survive, which, completely detached from the productive context, seem like ghostly building agglomerations endowed with great charm in their relations with the landscape. Severely degraded, partially collapsed, with no boarding docks dismantled or destroyed by sea storms, they take on a character of alienation. Witnesses of a past activity, today they are completely unused. Proto-industrial establishments for the processing of pumice were established precisely where the conformation of the coast below the mountain presented a sufficiently wide inlet. They are essentially of two types: the first with horizontal development, the second with vertical growth. While San Gaetano, Ghiozzo and Papesca (among the oldest settlements) are part of the first type and consist of a sequence of stone buildings and pumice blocks set directly on the beach; those of Th. Ferlazzo and F. La Cava are formed by the vertical juxtaposition of buildings resting on the slope, suitable for containing larger and more advanced machinery for sifting and drying pumice They are configured as sequences of terraces overlooking the sea, crossed by descent systems, steep staircases sandwiched between the blocks of production complexes. In the lowest part from which the jetties departed, warehouses were located with numerous openings to ensure good ventilation and considerable heights to stow large quantities of material for trading" [9].

The pumice structures and establishments are also punctually reported in the *Atlante dei beni Etno-Antropologici eoliani*, edited by Sergio Todesco [10]. Pumice quarrying is also one of the cornerstones of the *PTP - Piano Territoriale Provinciale*, the Territorial Landscape Plan of the Aeolian Islands, drawn up by Prof. Vincenzo Cabianca, which has allowed the Aeolian Islands to concretely advance their candidature and obtain the

extraordinary recognition as a UNESCO *World Heritage site*, not only because of their dazzling beauty but also thanks to their specific nature, representing an important model for the study of volcanology worldwide. The UNESCO *World Heritage Committee*, in fact, at its 24th session in Cairns, Australia (27 November - 2 December 2000), inscribed the Aeolian Islands on the *World Heritage List*, natural heritage category, with the following motivation: "The Aeolian Islands provide an outstanding record of volcanic island-building and destruction and ongoing volcanic phenomena. Studied since at least the 18th century, the islands have illustrated two of the types of eruption (Vulcanian and Strombolian) to vulcanology and so have featured prominently in the education of all geoscientists for over 200 years. The site still continues to enrich the field of vulcanological studies" [11].

A condition for the island's inclusion in the World Heritage List was also the closure of the company *Pumex S.p.A.*, involving all the areas of pumice processing and production, from the quarries to the embarkation jetties, prohibiting any further extraction activities, and forbidding any kind of spillage of industrial waste into the sea. UNESCO itself, in the Management Plan, decrees, under penalty of exclusion from the *World Heritage List,* the "prohibition of the continuation of mining activities in the areas included in the *World Heritage List* […]. Ban on the opening of any new mines" and proposes the establishment of a Pumice Geomining Park.

All this while agreeing that in reality said 'residues' of the industrial processing at sea were nothing more than the same pumice reduced to a very fine powder, thus not polluting material or material extraneous to the habitat, but the same substance of the mountain and sea bed. *Pumex S.p.A.* would therefore have had to stop its excavation activities and could only collect what had already been excavated. The rules envisaged a gradual entry into operation, to avoid bringing to its knees an activity that has always been the archipelago's main resource, reconverting activities and not wiping out the economy of 100 families.

Despite the fact that the last extension for extraction activities had expired at the beginning of 2006, *Pumex* would have continued to excavate and extract pumice stone anyway, as demonstrated by photos and surveys by air, sea and land, which revealed the continuous transformation of the morphology of the land, when it should only have been processing and exporting the stock material. On 31 August 2007, the area was seized and thus the hundreds of people working for *Pumex S.p.A.* suddenly found themselves without employment. Indeed, "one should not underestimate the social changes associated with the abandonment of old industrial areas". Areas that "based their identity, but also trivially their subsistence (in terms of employment) on the presence of such productive activities" [12].

Therefore, a redevelopment project was hypothesised, thanks to the participation of a mixed public-private company, which would have seen the area revitalised by renovating the buildings in good condition in order to make them usable for tourism, transforming them into tourist facilities of international attraction, a project that could also have absorbed the former employees; but due to various bureaucratic obstacles, the project was not carried out and since then the area has been in a state of almost total degradation and abandonment.

No longer able to work, *Pumex S.p.A.* was declared bankrupt and is still under the control of the bankruptcy court. Thus, in addition to the quarries and processing equipment, the buildings of *Pumex S.p.A.* were also left abandoned, thus risking the disappearance of all physical evidence of the pumice quarry and the industrial architecture that functioned there. And so in effect the 'factory' is no more and the museum dedicated to it is still not there. And in the meantime, the dismantling of the industrial structures of the and quarry and the sale 'by weight' of the metal have begun, and even the material of the one that should have gone into the other has been sold off bit by bit by the bankruptcy receivership, to the detriment of its historical value.

There has, of course, been no lack of proposals for these valuable areas in recent years. Mention was made of a 2002 proposal for a reconversion plan for the Pumice quarries that saw the geo-mineral park as the heart of the project with the preservation of the historical memory of the industrial processing of pumice stone. However, despite the fact that the plan had been incorporated into the UNESCO Site Management Plan approved by your department and the proposal repeatedly taken up by the Lipari City Council and the active administration, it was never put into practice.

Thus, the idea of a museum in the pumice quarries began to make headway, an idea cultivated for years like a dream by the enthusiastic lovers of memories of the *Centro Studi Eoliani* of Lipari, with the desire that the literary, artistic and landscape heritage could give life to a widespread mining museum.

It seems to be almost unanimously recognised that this heritage, linked even to mythology, should not be erased but neither should it be dispersed. Yet "Pumice stone, which along with obsidian was for millennia the island's only wealth, sold throughout the Mediterranean and then throughout the world in blocks for building (even the Pantheon dome is largely made of pumice and volcanic slag: otherwise it would have weighed too much), in smaller stones (for foot care since ancient times) or in very fine powder form (for beauty products), has in fact been all but abandoned for years. Worse: it is on the verge of an insane removal. An almost total erasure of the past", as Gian Antonio Stella well wrote in the Culture pages of the 'Corriere della Sera' in 2021. The journalist intervened, forcefully relaunching the proposal to create a widespread mining museum on the island of Lipari to prevent the memory of that landscape, social and cultural heritage linked to the pumice stone quarries from being lost. "What do you do with old mills and rails and trolleys and wharves, if the quarrymen who worked there have been parked in the limbo of socially useful work for a decade and the liquidators of that little old world are only in a damned hurry to get rid of the ferrous material to sell by weight, as if it were industrial scrap from the Ruhr?… A crime: that would be the loss of all memory of pumice and obsidian, the 'sister' stones, one white and the other black, generated by eruptions" [2].

A responsible answer to the cultural and civil battle started for the former pumice quarries came from the *Regione Sicilia* which declared its interest in building a museum and geo-mining park in the former quarries of Lipari.

Associations such as *Museimpresa, Federculture,* the Italian *Touring Club*, *Sicindustria* and the UNESCO Commission for Italy immediately joined in.

"The territory is the lifeblood of our country," and "the *Touring Club Italiano* is ready… to do its part so that Lipari and its quarries can become part of our future, a

future nourished by collective memory," declared Franco Iseppi, president of the *Touring Club Italiano,* immediately, intervening in the debate raised by Stella [13].

The *Regione Sicilia's* proposal to build a museum and geo-mining park in the former quarries of Lipari also seemed to journalist Antonio Calabrò, president of *Museimpresa,* to be "a positive and appreciable choice… Now it is a matter of quickly and effectively translating that choice into reality, to save and enhance a heritage that concerns the environment, industrial tradition and work and can help to increase the environmental and cultural attractiveness of the Aeolian islands and the resourcefulness of its inhabitants" [14].

On 15 October 2021, the entire area of the former pumice quarries in contrada Porticello on the island of Lipari, including the buildings and sheds with the machinery and equipment still detectable, was subject to a specific ethno-anthropological constraint with the relevant decree signed by the general manager of the regional department of cultural heritage and adopted at the end of a complex preliminary procedure conducted with celerity by the Messina Cultural Heritage Superintendency, pursuant to the Cultural Heritage Code. At the same time, the Sicilian Regional Government announced that it had signed the decree and intended to acquire the area for the establishment of a geo-mineral park and the creation of a museum of pumice stone processing for the environmental recovery of the areas where the former production complex is located and to preserve and enhance the island's ancient economic and cultural heritage.

In April 2022, the Sicilian regional government announced the go-ahead for the proposed purchase of the former pumice quarry, the property complex on the island of Lipari. This was decided by the junta, at the proposal of President Nello Musumeci himself. And so, after placing the lien and initiating a difficult confrontation with the liquidator commissioner, the action to recover and redevelop the mining site to return the area to the enjoyment of the island community and tourists seemed to have begun, says the Region. The necessary financial coverage was also found, amounting to EUR 4.5 million, as estimated by the regional departments of Energy, Technical and Cultural Heritage, to allow the development plan for the environmental recovery of the areas and the redevelopment of the former production complex to be launched, including the creation of the Pumice Museum and the Geomining Park.

Only a few months later, however, in August 2022, the TAR - *Tribunale Amministrativo Regionale* (Regional Administrative Court) declared "the constraint on the former pumice quarries to be illegitimate". The TAR, in fact, upholding the appeal presented by *Pumex S.p.A.*'s bankruptcy receiver, Prof. Massimo Galletti, declared that the imposition of the constraint was illegitimate. There were various objections, including the fact that 'although the preamble to the measure distinguished between portions of the area of interest as industrial archaeology and mining areas of ethno-anthropological interest, the operative part of the measure referred only to the latter interest: this contradiction would not have made it clear what the public interest to be protected would have been… The preliminary inspection report, necessary for the evaluation of the property, did not contain the dating (necessary to exclude, as required by law, property less than 70 years old) and description (for the evaluation of the functional connection with the protected interest of the property) of the movable and immovable property to be bound. These elements were also lacking in the subsequent technical-scientific report, on the basis of

which a *unicum* of more than 586,000 square metres and volumes of more than 1,855,000 cubic metres was allegedly bound indiscriminately. In relation to the machinery of the most recently built plant, the same report, in the statement that it was machinery of the 1950s/60s, testified to their "age" of less than 70 years. The measure would not have distinguished the assets at all on the basis of their different age. … the *Soprintendenza*'s decision that had admitted, in 2011, the hotel accommodation use of all the *Pumex*-owned buildings in the Porticello area" [15].

The TAR's decision has of course complicated the process for the establishment of the geo-mineral park in the Porticello and Acquacalda pumice area and the pumice museum announced by Musumeci, who in the meantime has been replaced by Renato Schifani as President of the Sicilian Region from 13 October 2022. Since the cancellation of the constraint, there has been no more talk of plans for the former pumice quarries on Lipari. And so, "To the disappearing proto-industrial quarry landscape, the architectural artefacts of the period survive, which, completely detached from the productive context, seem to be ghostly building agglomerations endowed with great charm in their relationship with the landscape. Severely degraded, partially collapsed, with no boarding docks dismantled or destroyed by sea storms, they take on a character of alienation. Witnesses of a past activity, today they are completely unused" [9].



Fig. 3. Historical analysis of pumice working, from Milena Mollica's project thesis. Photos from the private archives of Antonino Costa and Claudio Merlino and Antonietta Liotta Papocchia. A great deal of material, much of it still unpublished, was found, thanks to the latter, by Clara Stella Vicari Aversa.

3 Ideas for a Possible Urban and Environmental Regeneration Project for the Lipari Pumice Quarry Areas

The future of the industrial archaeological heritage of the former pumice quarries on the island of Lipari still appears to be rather uncertain, and their destination as a Geo-mineral Park is still in a state of strong expectation. Yet "the experiences of regeneration and redevelopment of disused industrial areas" in various parts of the world "have not only achieved important results with respect to the restitution to the community of areas and spaces hitherto denied," but it is sufficient to analyze examples of them, in large and small disused areas, urban and suburban, to note how a "process of legitimation of cultural heritage as a collective good and as an inescapable resource for a sustainable project of economic and social growth" has started almost everywhere [16].

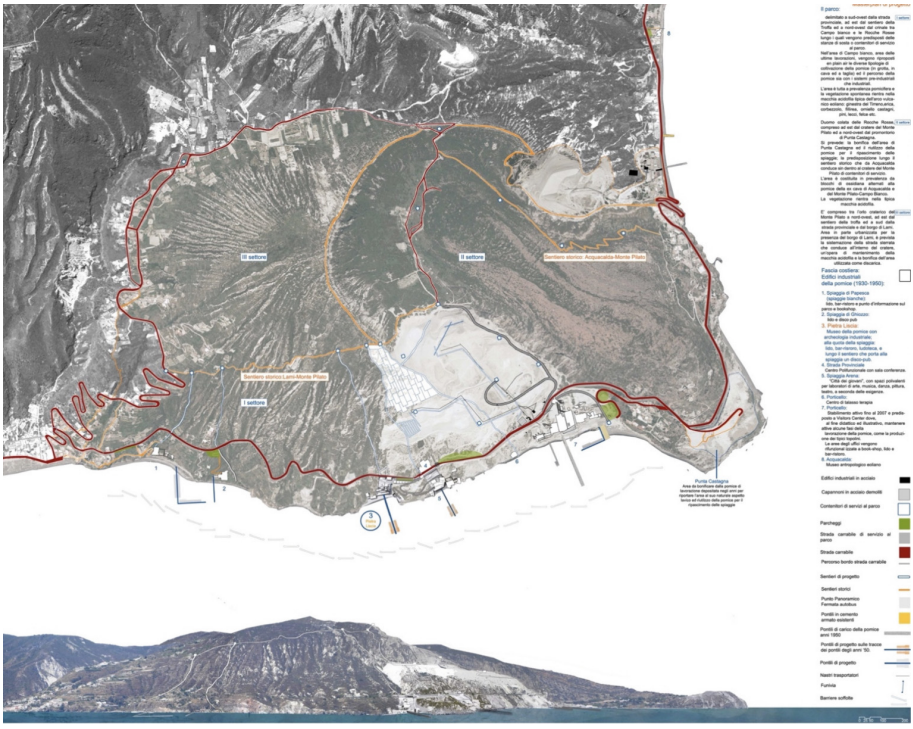

Fig. 4. The Pumice Geomining Park. From Milena Mollica's project

Meanwhile, time passes and the valuable pomiciferous area is still waiting for its regeneration, despite the fact that ideas and projects over the years have been produced and several of them even partially carried out. Here it is that taking cues from interesting projects by actualizing them, could be a way to restart and catch up to give further support and impetus to new proposals and projects that are as inserted and integrated into the context as possible. Among the various projects there is one in particular, which has also been exhibited at the Pumice Museum set up at the Terme di S. Calogero,

which was drawn up with extreme skill and passion by an architect from Lipari on the occasion of her thesis at the *Università degli Studi Mediterranea di Reggio Calabria*, Italy. This is a project of "Urban and Environmental Redevelopment of the areas of the Lipari Pumice Quarries," a design thesis by Milena Mollica, supervisor Prof. Franco Cardullo, co-rapporteurs: Prof. Arch. Clara Stella Vicari Aversa, for the study and design elaboration in relation to the particular context and landscape; Prof. Arch. Consuelo Nava, for sustainability and environmental aspects. (Figs. 4, 5, 6).

The basic idea takes up what UNESCO recommended at the entry of the Aeolian Islands in the *World Heritage List*, that is, a Pumice Geomining Park that integrates and harmonizes within it different needs: environmental and territorial, for a hydro-geological and ecological reorganization of the area; urban-architectural, to recover and revive the ruins of the pumice plants, inserting various activities related to the park, the museum and the sea, equipping the area with appropriate lighting, bicycle and pedestrian paths with related rest areas, bus stops and parking; economic, to generate employment for both former pumice workers and other professional figures in various disciplines beyond the tourism sector; socio-cultural and historical, to ensure the historical memory with the creation of the Regional Museum of Pumice related to industrial archaeology, as has already been done for archaeology with the Aeolian Regional Archaeological Museum "Luigi Bernabò Brea". An attempt was made to shape an idea, starting mainly from the territory and its stock, envisaging a park that covers about a quarter of the island in the northwestern part included between Canneto and Acquacalda and its edges are marked: along the coast by the pre-existing pumice buildings that can be accessed by several paths laid out along the provincial road that runs all along the island passing also through Canneto and Acquacalda; in the bosom of the mountain by an old path, now partly passable, that starts from Canneto, crosses the small district of Lami, follows the crater rim of Monte Pilato and then descends along the Rocche Rosse until it reaches Acquacalda.

Along the coastal strip, below the provincial road, it is imagined to recover and restore all the ruins of pumice processing, converting them back into activities related to the park, the sea, and the pumice museum; beach nourishment is planned (using material from Punta Castagna) and the provision 50 m from the beach of soft barriers to lessen the impacts of sea currents; the reclamation of the old loading docks buried underwater and their restoration, along with others, to serve the new functions for mooring boats.

White volumes of industrial archaeology are scattered along the 8.4 km of coastline and, starting from Canneto to Acquacalda dot various places: Spiaggia di Papesca, known as *Spiagge Bianche* because pumice dust was deposited on it until the late 1980s, where the former industrial buildings are planned to be used as a lido, seaside bar-restaurant and Park information points with book-shops; *Spiaggia di Ghiozzo*, where the white volumes, among which an old chimney stands out, host a lido equipped by day and disco-pub by night; *Pietra Liscia*, where the Th. Ferlazzo and F. La Cava is being reconverted into the Pumice Museum, with an equipped lido, first aid area, playroom, bar-restaurant and disco-pub around it, with accessibility both from land by a system of stairs that start at street level and lead to the various heights, and by a cable car powered by photovoltaic energy, and by sea, and both by land and sea there is provision for parking and mooring, placing a new pier on the stock of the previous loading dock; the *Spiaggia Arena*, where



Fig. 5. Pietra Liscia area. Status and Proposal. From Milena Mollica's degree project thesis.

a Youth City is envisioned, with a multipurpose center and spaces equipped for art, painting, music, dance, singing, literature, and theater workshops; *Porticello*, where in the former *Eolpomice* building a Thalassotherapy center accessible, as above, both by land and sea, in the *Pumex S.p.A.* building a Visitors center is envisaged (this is the plant that remained active until the 2007 seizure and where therefore to think about a re-proposition of the workings, for the obviously didactic and illustrative purpose also with bar-restaurant and book-shop); *Acquacalda*, where a Museum of Aeolian Anthropology is planned in the former mill where the only examples of flat ovens are still present, to tell the story of the Aeolian Islands from a human and socio-cultural point of view, both through written, audiovisual, photographic and material evidence, and through its territorial resources over the centuries, such as the sea, pumice, cultivation, tourism, and cinema.

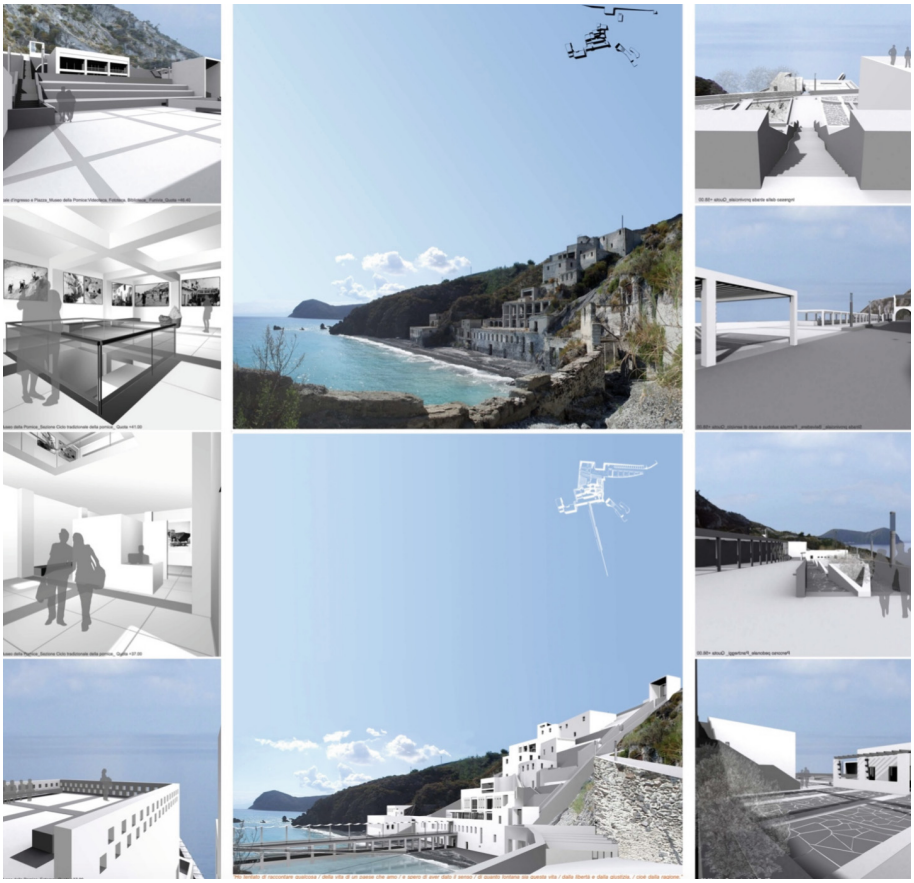

Fig. 6. Pietra Liscia area. Photo and Project views. From Milena Mollica's degree project thesis.

4 Conclusions. Pathways to Be Taken to Preserve and Enhance Industrial Heritage, Memory, History and Identity of the White Aeolian Shores

The cues and suggestions arising from this "journey" refer to many possible paths to be taken and followed. Moreover, even the very concept of "travel" in the landscape, of walking in places, refers to a "multitude the itineraries that come to weave, in a kind of spider's web, a geography of 'paths', the most varied… Following an infinity of traces, from the culinary to the sporting, from the cultural to the mystical, from the literary to the musical, etc." [17].

We need to treasure this and other projects, working to ensure that all this ancient economic-cultural and landscape heritage present in the largest of the Aeolian islands is not dispersed, but rather properly protected and enhanced. Embracing the definition of landscape as "an essential component of the people's living environment and the foundation of their identity" [18],) it seems impossible to still think of waiting and not

initiating all the necessarỳ activities to heal this great physical-temporal rift with an adequate regeneration project, while instilling the long-awaited concrete opportunity for redevelopment and development. It is a matter of finally initiating a "practice of reuse" and "transmission, through time, of artifacts and values," which, after all, has always been done, since "the custom of grafting and recycling, in the architectural and urban fields," has "never ceased to characterize our ancient world" [19]. Of course, in doing so, while embracing a brownfield approach and thus utilizing existing facilities, infrastructure and resources, there is a need to seek wherever possible to integrate state-of-the-art technologies, efficient processes and sustainable practices; a careful design that revitalizes and reactivates the area but at the same time is capable of preserving and enhancing its industrial heritage, memory, history and the very identity of the places.

The recovery of industrial heritage has increasingly become "one of the strategic levers for the cultural revitalization of cities and territories and for new urban regeneration programs, which make it possible to give adequate valorization to the assets of industrial civilization and return them to the public as a collective cultural heritage." It is no longer sufficient to "the albeit sacrosanct defense of historical memory and value systems related to the local community," but it is necessary to face new challenges and "the development of increasingly innovative and diversified strategies and policies for conservation, reuse and valorization" [20].

Making the most of all this, it is necessary to recover as soon as possible an extraordinary area that, despite years of neglect and neglect, remains strongly identifying the island and its great environmental and geological heritage that is constantly changing and belongs strongly to its history. (Fig. 7).

The procedures are not simple and the interventions appear complex. In the project, it is necessary to work systemically not only on innovative proposals for the reuse of the white buildings but also on access routes and the securing of slopes, as well as against inherent fragilities and hydrogeological instability.



Fig. 7. Photos from the sea of the white unicum of volumes, excavations and pumice mountains from Papesca - Pietra Liscia (left) to Porticello - Acquacalda (right). August 2023. Photo by Clara Stella Vicari Aversa.

The area as a whole is certainly in a rather precarious condition, but it remains a broad area that is definitely highly articulated and desirable to be approached with a multidisciplinary vision, having to address not only the physical configuration but also the interaction with ecosystems and the environmental [21]. A project must be designed that is also sustainable because it is aware of its omplexity, bringing together and consolidating the various social, economic, technological and environmental benefits [22].

Only if a synergistic collaboration between the region and the municipality can finally and effectively be established, perhaps even with the contribution of cultural actors in the area, can we expect to achieve the goal. “If conceived, planned and managed from an overall perspective on an urban and territorial scale, the transformation of these assets can trigger an overall regeneration that returns to old and new inhabitants an environment more suitable for individual development and collective growth, fostering social cohesion and competitive capacity on a regional, national and international level” [1].

It is necessary to keep the attention on the area alive and initiate a project as soon as possible, also on the basis of what has been excellently studied, investigated and planned by our passionate colleague from Lipari, to make sure that the ancient historical heritage of pumice and obsidian mining on the island, which is of significant value, is not dispersed, but rather is properly protected and enhanced in its being remembered.

“But how to remember and what to remember in a world that increasingly seems to be becoming similar to the Borgesian Library of Babel?” [23]. And indeed, these mountains, the result of even very hard work over many generations, seem to remind us almost of J. L. Borges’ “The Library of Babel,” a Library that “existe ab aeterno,” in which not only does the book of Truth appear to be present, but also every possible variant of it and even its opposite, with the relative possibility (or impossibility) of distinguishing them.

However, it is a matter of working on the discipline of memory to assimilate the past to understand how to transmit it and at the same time make it better and then, thanks to the project, take a step forward to deliver it in a new and optimal way to the present and the future. “He who follows others never goes before him,” wrote the great Borromini, “And I certainly would not have set myself to this profession with the aim of being only a copyist” [24]. Just as only as a great connoisseur of the past Borromini himself could afford the luxury of surpassing and modifying it, in the same way what is needed for the extraordinary former pumice quarries is a proper reappropriation of the past, of what has been for them, thinking at the same time, foreshadowing and working already for what they will be or can be, continuing to keep “the rudder on the starboard side” to the goal even if the sea is stormy. Sooner or later, if everything possible is done to make it happen, the quiet as well as the project, on these extraordinary and never satiated shores, will come.

Wonderful beloved banks overlooked by a blinding white cascade of pumice continually shaped by time and men; a cascade that, somewhat like the library of Babel, appears “unlimited and periodic. If an eternal traveler crossed it in any direction, he would find, after centuries, that the same volumes are repeated in the same disorder (which, repeated, would be an order). My loneliness rejoices in this elegant hope” [25].

Contribution Author. The research represents also part of the first results carried out in the departmental research laboratory *STRETT-ARCH_Strait Regeneration, Territory Transformation, Architecture* (of the Department of Architecture and Territory - dArTe, University Mediterranea of Reggio Calabria) and in a joint convention between Universities entitled *A.Ma.Te Sponde - Architetture, MAre, TErritori, Città e Paesaggi tra le Sponde dello Stretto-*, in both of which he is among the scientific leaders.

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Contexts of Reuse and Regeneration. Defense Sites and Disused Infrastructure in Coastal Areas

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Abstract. Urban regeneration must solve the problems of physical and social degradation by regenerating areas in decline according to some indications aimed at making the interventions sustainable and at the same time the territory resilient. This strategy must provide, in the medium and long term, the prerequisites for sustainable and lasting development by improving economic, physical and social aspects. The cases analyzed, which are based on experiences of effective intervention in decommissioned military areas, located in the coastal cities of Reggio Calabria in Italy and Palma de Mallorca in Spain, represent examples of good practices that can be replicated in other contexts precisely because they respect some of the conditions mentioned above. The reorganization and recovery or reconstruction of these particular areas, especially those located within or close to the existing city, can become an opportunity to involve communities in participatory practices aimed at intercepting local demand. This research work focuses on a preliminary step of analysis of the literature which allows us to highlight the optimal conditions and solutions for achieving the objectives of resilience, territorial and social inclusion, and ecological transition in light of the dynamics of the dimensions involved and the current planning guidelines.

Keywords: Social and territorial inclusion · urban regeneration · reuse of brownfield · infrastructure planning

1 Introduction: Urban Regeneration and Reuse of Brownfield

Urban regeneration, in the light of current guidelines, urgings from European Union and United Nations guidelines, is a mode in which a type of public policy is expressed, which must be comprehensive and integrated by seeking to solve problems related to the physical and social degradation of "critical urban pockets" and to redevelop areas in decline (1). This strategy, which operates at multiple levels and through the contamination of sectors, must provide, in the medium and long term, the prerequisites for

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sustainable spatial development by improving economic, physical and social aspects (2). The analyzed cases that are based on experiences of effective intervention in disused military areas, one Spanish and the other Italian, represent two good practices that can be replicated in other contexts, for the following reasons.

Abandoned military, industrial, or infrastructure areas, while not an easy problem to solve due to the significant costs required for recovery, decontamination, and re-functionalization, represent a priority for the safety and health of exposed communities. Not only that, the reorganization and rehabilitation or reconstruction of these particular areas, especially those located in or near areas within the existing city, can become opportunities to engage communities in participatory practices aimed at intercepting local demand. Such areas, especially if they are well connected in terms of infrastructure with the main connecting road system or with areas of strategic interest, such as port, airport and railway infrastructures, productive activities and services of extra-urban relevance, can represent an opportunity for the economic and social revitalization of the context and territory.

Today, in the literature on development planning, improving the quality of life of citizens and achieving performance standards related to the city's ability to deliver services, high digital specialization while ensuring ecological transition and social and territorial inclusion, requires at least three enabling factors: 1) meeting the demand for space through smart solutions to make optimal use of new "reuse places"; 2) innovation to create development opportunities and competitive environments; and 3) configuring a highly specialized environment to attract creative ideas and investment opportunities.

There is a common characteristic in the cases under study, which is that they are located near coastal areas and port systems. As is well known, the reorganization of new public spaces through the reuse of the existing can be successful if the functional redevelopment takes into account the supply of sustainable mobility and an efficient transportation system in line with current and future demand, also because of the effects produced by regenerative processes, such as increased flows of users, goods and people (11). Urban regeneration means new developments and improvements in the condition of dilapidated urban areas the birth of a new spirit (3).

There is a "complex" relationship between urban settlements, ports, production facilities and defensive systems. Port cities (whether city/port or city with port) have different characteristics from port areas, as known for the obvious dilation of the space-function relationship. The thickening of functions in port cities/towns makes it difficult -and at the same time necessary- to find a planning response that translates into a tool for effective land regeneration. In fact, the issues highlighted become "problems" that are not easy to solve when we talk about port areas (such as the one concerning the cities of Trieste, Taranto, and Cagliari in which the city and the port interact without welding and promiscuity of functions), but they become a priority, imposing an effective response, when city and port are integrated – for example realities such as La Spezia, Savona, Naples or Ancona – and the existing interrelationships influence both port and urban planning and regeneration.

Regeneration is sometimes, in rare cases, not complex when the re-functionalization confirms the previous so-use. This is the case, for example, of the new forestry barracks and carabinieri station in Verghereto, which provided for the demolition of the existing

structure the construction of a new barracks with improvements and additional provisions, including the use of a load-bearing structure consistent with the indications of the State Property Agency, built for the first two floors in reinforced concrete, including the basement, while the top level with X-lam partitions. The wooden construction elements that improve the landscaping and are completely prefabricated: dry assembly use guarantees advantages in terms of quality and sustainability of materials (4). The relationship of non-randomness of urban, port and defensive settlements is different for small and medium-sized ports and towns, where some defense installations or small defensive garrisons have sprung up along the coast to ensure military control by sea: ports that retain a tourist vocation and small towns composed of two distinct and different parts, unified functionally, since time immemorial, but only in the last century really welded together (12). Part of the urban core is arranged on the promontory and often arises from the joining of waterways to the sea, in the coastal area, on the other hand, the coastal core is characterized by activities and services related to fishing or maritime activities in general. The two centers are usually-a few hundred meters apart as the crow flies-experiencing a certain economic complementarity: sailors, fishermen and artisans in the sector settled on the marina, while farmers preferred the high zone near the arteries connecting with the interior of the territory. Defensive works and military installations were located in control positions and close to land and sea transportation infrastructure.

2 Case Studies

By looking at two sites i.e., Son Busquets and DIA of Reggio Calabri, we attempt to unearth the unique opportunities that they offer for urban renewal and community engagement. Son Busquets stands poised to play a pivotal role in the rejuvenation of its neighborhood, with plans for a new civic and pedestrian axis set to link it with the historic center, breathing new life into the area. Once home to barracks, its well-preserved buildings and lush surroundings offer immense potential for creating green spaces and vibrant public areas. On the other hand, the DIA of Reggio Calabria holds a rich history, having served as a fuel depot during World War II. Going through patch of transformation, remnants of its past remain now that includes a tunnel and the Manganelli multipurpose facility. Located in Santa Caterina, near the port and major highways, this site holds promise for future development while honoring its military heritage.

Son Busquets

Son Busquets could assume an important aggregative role in the planning process of the new civic and pedestrian axis – Cotlliure – that would serve to regenerate the neighbourhood and effectively connect it with the historic centre. In the Camp Redó neighbourhood, the Son Busquets site is also emerging as a valuable solution to the need for new green areas and quality public open spaces. The barracks were closed in 2000, leaving a complex of buildings consisting of 16 ground-floor hangars with an east-west orientation and another 18 smaller hangars with a north-south orientation. These and other artefacts are in a relatively good state of preservation, having been built according to the tradition of the time, with marés load-bearing walls and pitched roofs made of Arabian tiles of historical and cultural value. It is set in a context of interesting vegetation, with productive potential (Table 1 and Fig. 1).

Table 1. Barracks - headquarters of the 91st Mixed Artillery Regiment (RAMIX 91)

OLD MILITARY QUARTER OF SON BUSQUETS	**REGION:**	**Spain**
	CITY:	Palma (Majorca)
	NAME:	
	INITIAL DESTINATION: *Military barracks* *Airport, military infrastructure* *Military base/shooting range, exercises* *Other*	Barracks - headquarters of the 91st Mixed Artillery Regiment (RAMIX 91).
PHYSICAL AND DIMENSIONAL CHARACTERISTICS	AGE OF CONSTRUCTION:	1949 (presumed era)
	PROPERTY:	Public
	SIZE (RANGE): <1000 SQM >1001 E <10.000 >10,001 SQM	110.000 m2 Total built space is 27,743 m2
	RELATIONSHIP TO THE URBANISED CONTEXT *Interior* *External in continuity* *External in suburban areas*	***Interior***
	STATE OF DISUSE: *Abandoned* *Underused*	Abandoned The buildings are in a relatively good state of preservation and are considered to have a certain charm because they were built in the tradition of the time.
REGENERATION STRATEGIES	CONVERSION IMPLEMENTED OR IN PROGRESS:	Abandoned since 2000, it is regarded as Palma's last great urban void and is still awaiting architectural and urban renewal to respond to the demand for urban transformation of the surrounding neighbourhoods
	MIXED WITH PREVALENCE OF: *Services and urban amenities of a social and aggregative nature* *Business/office centre*	There are currently abandoned artefacts and potentially productive greenery. A project is hoped for to create urban services and amenities of a social and aggregative nature
COMPLEXITY FACTORS	CONTAMINATED SITE:	-
	WIDESPREAD URBAN DECAY:	Camp Redó, is a very dense peripheral neighbourhood that suffers from serious problems of physical and social degradation, with severe urban discontinuity and poor connection to the historic city centre
	LACK OF SERVICES AND SOCIAL DISCOMFORT:	The General Urban Development Plan of Palma of 1973, the current plan of 1998 and its imminent successor, contemplate for the urban expansion of Palma the reinforcement of six civic axes (west or east Fàbrica, Ocells, Blanquerna-Cotlliure, Arxiduc, Nuredduna and Foners). Since 1973, only 14% of the 7,110 planned 'civic' metres have been implemented.
	MANAGEMENT COMPLEXITY:	The regeneration of the Old Military Quarter of Son Busquets could become an opportunity for the urban planning and development of the Camp Redó district, a densely built-up area with problems of physical and social decay.

Note: Elaborated by Celestina Fazia



Fig. 1. Old Military Quarter of Son Busquets, Source: Gallery of Mallorca's Abandoned Buildings - 9 (archdaily.com)

Construction of the Son Busquets barracks (within the city walls that were built in 1575), began in 1949 and was completed in 1952. Regarding the regeneration of the now decommissioned area, an agreement was signed between the Ministries of Defense and Transportation, Mobility, and Urban Agenda; following this agreement, the structure was handed over to the Entedad Pública Empresarial de Suelo (SEPES) for the construction of social housing on 50% of the available land. The remaining 50% will be set aside for public use and the creation of green areas. According to the Special Interior Reform Plan (PERI), defined through a participatory process, the housing will be public and will be rented at reduced prices, accessible to people with different incomes. There will be 20,000 square meters of tertiary space for small businesses and workshops for job creation (5).

DIA of Reggio Calabria

The site originally was a fuel depot for military use. Used during World War II, it housed three tanks; of these, one was demolished to make way for the construction of the Manganelli multipurpose facility (6). Within the area was a building of about 80 square meters in use by the firefighting squad and which had been disused for several years. Within the project area with access from the elevation of Enotria Street, there was a tunnel used during World War II characterized by a low arch section with dimensions 2.00 m × 2.50 m.

The area is located in the northern area of the city of Reggio Calabria in the locality of Santa Caterina, near the port and the mouth of the Salerno-Reggio Calabria Highway.

The 'area of intervention, placed on Enotria Street, is located in front of the Multipurpose Center Manganelli opened in 2014 that houses the offices of the police headquarters of Reggio Calabria.

The parcel subject to intervention is indicated in the tables of the P.R.G. in zone F called “Areas for military headquarters and equipment,” these are areas subject to military jurisdiction (Figs. 2 and 3).

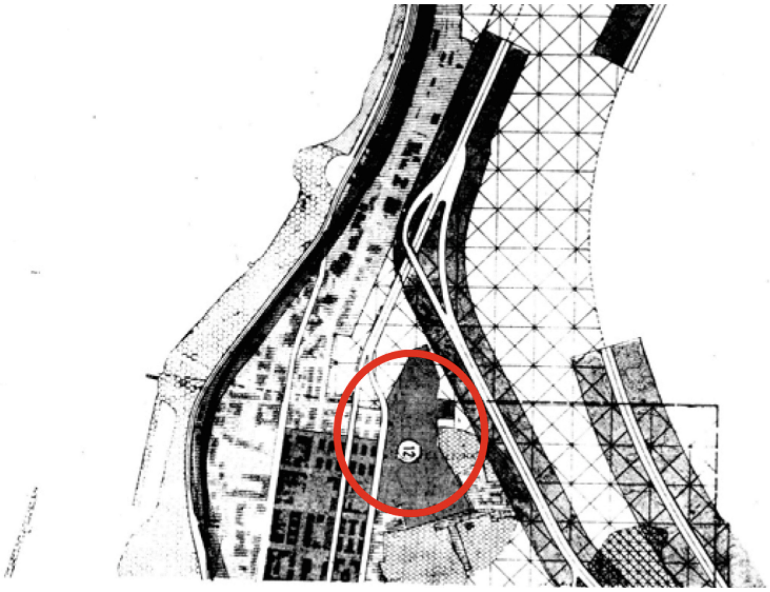

Fig. 2. General Regulatory Plan, PRG, of Reggio Calabria, approved in 1970, Source: Piano regolatore generale comunale - Comune di Reggio Calabria - Trasparenza

According to the PSC, the ‘area falls within the UTA, Unified Territorial Area, II.1 of the consolidated or forming urban fabric, oriented mainly to the consolidation of the recent city. For the project of the new headquarters DIA, Anti-Mafia Investigative Directorate, several specialized investigations and analyses were carried out: analysis of interference with the overhead and underground networks of services and design resolution (water network, black water and storm water disposal networks, power supply network, gas and telecommunications),

As a result of Law No. 177/2012, on the subject of remnants of war, which amends and supplements the T.U.S. 81/2008 on occupational safety, the possible definition of a level of risk of non-acceptability implies the need to take the necessary preventive and protective measures suitable to eliminate or at least significantly reduce the probability of occurrence of the potentially harmful event. In this second case, one has the power to provide for subsequent conventional safety measures, defined as “ordnance clearance,” to be activated in the case requested under the aegis and binding opinion of the competent Ministry of Defense pursuant to Art. 22 of Legislative Decree 66/2010 (New Military Code). So, the area affected by the implementation of the DIA, was subject to specific checks, analyzed in relation to geological characteristics, the presence of possible inhibitory and protective constraints. The presence of possible archaeological finds, seismic risk.

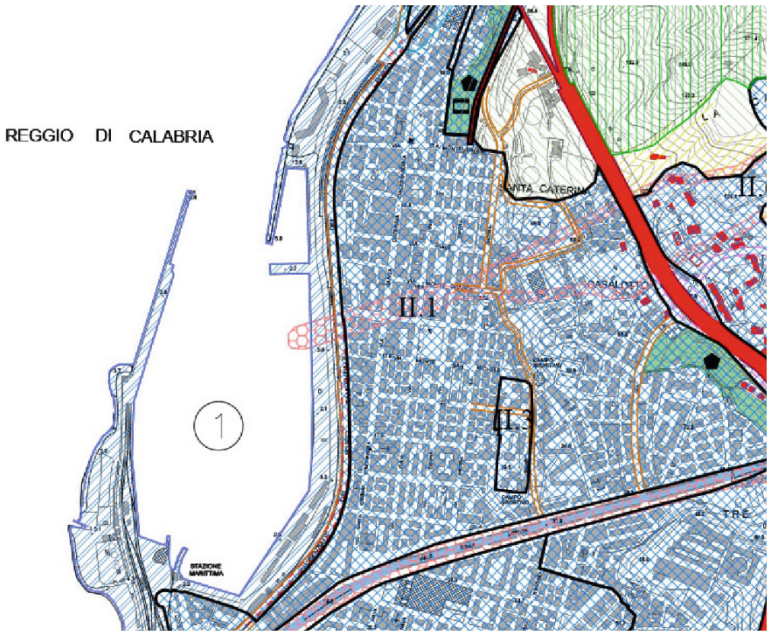

Fig. 3. Excerpt from the Municipal Structural Plan, PSC, of Reggio Calabria, adopted in 2019, Source: Comune di Reggio Calabria - Notizie - PSC - REU

The design of the DIA headquarters, it will also host the 12th Mobile Department and the State Police-was drafted to meet the needs of the Administration receiving the property and in compliance with the following criteria

- Flexibility of spaces and solutions to eliminate architectural barriers, including a tactile pre-course with related aids in the area open to the public, services and conference room on the ground floor. The tactile language that will be used is LOGES-VET-EVOLUTION (LVE) and is achieved by inserting special tiles into the flooring, the different types of which can be easily felt underfoot and with a white cane;
- Work environment quality (systems to improve the quality of 'acoustics), indoor air healthiness and respect for the microclimatic conditions of the site
- Energy conservation (photovoltaic system on the roof slab)
- Ease of maintenance and durability of materials.

The sizing of the building was carried out by means of the sq m/addict parameter
Total area of intervention area: 3,675 m^2
Floor area: 1,246 m^2
Covered surface area (SC): 985.20 m^2
Permeable surface area (SP): 1,847.55 m^2
Total surface area (ST): 4,628.92 m

The new building has four above-ground floors and a basement floor for the garage and technical rooms. On the ground floor in addition to the archive and wellness area is the conference room. The first and second floors are devoted to offices and guest quarters. On the other hand, the third floor is dedicated to the apartment for the manager. The building is characterized by a central covered courtyard lit from above with natural light.

The functional arrangements, distributional characters, and orientation of the envelope were designed to improve the building's energy and functional performance by reducing resource consumption and emission of pollutants. Through (i) controlled mechanical ventilation system with heat recovery; and (ii) room primary air diffusion, domestic hot water production systems. Draining outdoor paving plays with the perimeter hedge made of *teucrium fruticans and Phyllirea angustifolia* an important role in surface water management. Irrigation of the hedge and the portion of the lawn that follows the ramp is done with reclaimed meteoric water.

The intervention is an urban redevelopment of a portion of land that is no longer functional for the Navy and involves the construction of a new building that will house the headquarters of the D.I.A. (Direzione Investigativa Antimafia) in the Santa Caterina area of Reggio di Calabria. This new headquarters will be built on a portion of the former Navy fuel depot compendium, which formerly housed three metal tanks connected to the port via underground pipes. To make room for the construction of the new state-owned facility called "Manganelli Multipurpose Facility," one of the three tanks was demolished. Thus, the main objective of the intervention is to build an adequate and functional headquarters for the D.I.A. in this specific area of Reggio di Calabria (Table 2).

The intervention is an innovative building type that follows the most advanced environmental criteria and the best solutions for energy efficiency. This is an excellent approach to ensure sustainable construction and reduce environmental impact in addition to the fact that the intervention will contribute to the creation of a "Security Citadel" within the state-owned complex. The addition of the headquarters of the 12th Mobile Department of the State Police, together with the existing Multipurpose Center, will allow the concentration of several security-related functions in one area. This synergy between different security-related entities can lead to greater collaboration and coordination among various institutions, fostering a safer and more secure environment for the community. Especially because of the Citadel's location, which affects the area north of the city, playing a garrison role in a critical urban context affected by a high number of crimes attributable to organized crime (Fig. 4).

Table 2. D.I.A. (Direzione Investigativa Antimafia) in the Santa Caterina area of Reggio di Calabria.

D.I.A. (Direzione Investigativa Antimafia) in the Santa Caterina area of Reggio di Calabria	**Region:**	**Calabria, Italy**
	City:	Reggio Calabria
	Name:	D.I.A. (Direzione Investigativa Antimafia) in the Santa Caterina area of Reggio di Calabria.
	Initial destination: *Military barracks* *Airport, military infrastructure* *Military base/shooting range, exercises* *Other*	State-owned former fuel depot complex of the Navy, which formerly housed three metal tanks connected to the port via underground pipes.
physical and dimensional characteristics	Age of construction:	1943 (presumed era)
	Property:	Public
	Size (range): <1000 sqm >1001 e <10.000 >10,001 sqm	3.675 mq
	Relationship to the urbanised context *Interior* *External in continuity* *External in suburban areas*	Suburban area located in the northern part of the city. It is located in the vicinity of the port of Reggio Calabria and more exactly upstream of Via Enotria, traveling along it in the direction of the Mediterranean highway.
	State of disuse: *Abandoned* *Underused*	Abandoned
regeneration strategies	Conversion implemented or in progress:	Urban redevelopment of a portion of land no longer functional for the Navy, providing for the construction of a new building that will house the headquarters of the D.I.A. in the city of Reggio di Calabria.
	Mixed with prevalence of: *Services and urban amenities of a social and aggregative nature* *Business/office centre*	The presence of the decommissioned military works represent two of the interferences surveyed within the area affected by the works: 1. presence of an old one-story above-ground building of about 80 square meters that housed the firefighting team; 2. presence of the underground tunnel.
complexity factors	Contaminated site:	partially, presence of disused tanks
	Widespread urban decay:	confined to some areas of the St. Catherine neighborhood
	Lack of services and social discomfort:	critical urban context affected by a high number of crimes attributable to organized crime
	Management complexity:	no

Note: Elaborated by Celestina Fazia



Fig. 4. Top left: underground tunnel; Top right: fire team building; Bottom: exterior view of the building-Entrance area. Source: Executive project-interference report (2018)

3 Conclusions

In addition to the social-environmental-economic aspect, there are several factors that do not incentivize the reuse (7) of decommissioned military real estate assets (whether to be reclaimed even partially). In coastal areas and within the port cities, the issue of brownfields takes on a certain significance that stems from the exposure of urbanized areas to environmental and technological risk factors. Such "adverse situations" can be summarized as follows:

- the bargaining power of those who hold the asset (usually it is the Ministry of Defense) with respect to the future use (8) of the areas and the economic role of the state in decision-making over state-owned areas that lose their institutional function;
- the overlapping competencies between subjects and levels and the "paralysis" affected any emerging conflicts; all of which indirectly affect the loss of value (9);
- the high cost required for reuse in addition to the poor level of degradation;
- the constant crisis in the real estate market and the construction industry;

– the continuous adoption of new legislation with the consequent introduction and modification of procedures that are not always well defined and often contradictory to each other, but also the timing of bureaucratic and land-government procedures;
– the predominantly financial approach of alienation procedures and the adoption of sector regulations that should economically incentivize the rationalization of the armed forces, but do not integrate new functions to be attributed to the decommissioned assets into the process;
– a lack of knowledge about the current state of military real estate assets (in use, underutilized, abandoned or to be included in the lists of alienation programs);

These circumstances have strongly contributed to the creation, of military "urban and suburban voids" that threaten to compromise the coastal, rural and mountainous Italian landscape (10). The first area through which the coastal city becomes recognizable is the port area, (the case of Genoa and Naples); within or in close proximity is the "backport strip," which is the intermediate zone between the port that becomes the waterfront and the consolidated urban fabric, sea-inland graft routes, the consolidated city. In it were located many manufacturing or military facilities, now disused. One solution could be to return these facilities to the port infrastructure (e.g., by strengthening the relationship between the energy/transport/infrastructure compartments) or to weld them to the specific urban functions of the city that is set back from the port (mixed cultural/aggregative/receptive, or purely social destinations) (11, 12).

The challenges associated with the reuse of decommissioned military real estate assets, particularly in coastal and port city contexts, are reflective of broader issues of bureaucratic complexity, financial barriers, and institutional inertia. These obstacles, while specific to certain regions, resonate with similar challenges worldwide, especially in areas with high environmental and technological risk factors. The creation of military "urban and suburban voids" is a common concern, threatening landscapes and urban fabric integrity. However, the proposed solutions, such as integrating disused facilities into port infrastructure or repurposing them for urban functions, offer replicable strategies for addressing similar issues globally. By strengthening interdepartmental cooperation, streamlining regulatory processes, and fostering public-private partnerships, communities can transform liabilities into assets, revitalizing landscapes and enhancing urban resilience across diverse contexts.

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The Role of Beauty in the Sustainable Regeneration of the Historical Centres: The Upper Town of Bergamo

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Abstract. The ongoing debate on new urban planning and regeneration strategies is crucial for the future of old towns, which are still struggling with significant obstacles. This is an important issue that involves the political class, professionals, and citizens, and requires more investigation. Due to market pressures and insufficient regulations, historic cities in today's world are at risk from both old and new dangers. The growth of mass tourism has resulted in depopulation, the loss of traditional production and commercial functions, and consumption phenomena. A generalized trend which if, on the one hand, sees the industry of tourism as an important driving force for the development of historic centres, on the other hand induces negative consequences that careful planning should be able to counteract. This paper focuses on *Città Alta*, the upper town of Bergamo. The city was once unhealthy until Luigi Angelini's Recovery Plan was implemented, which allowed it to adapt to modern life without losing its identity. In 2017, UNESCO recognized its fortifications as part of a series of transnational sites that includes the *Serenissima*'s most comprehensive and innovative defence networks. Since then, tourism highly increased and, at the same time, the Municipality of Bergamo developed new conservation and valorisation projects, starting from the idea that both social inclusion and beauty in the built environment would help in promoting health, well-being, and sustainable growth. A substantial question that the authors intend to discuss.

Keywords: architecture/urban regeneration · cultural heritage conservation and valorisation · sustainable cities

1 Introduction

In Italy, urban planning policies – also by virtue of the provisions set out in the recent National Recovery and Resilience Plan (PNRR) and from a public interest perspective – are increasingly focused on reducing land consumption, regenerating existing building stock, and valuing sustainable architectural projects. In this context, historic centres are faced with daring challenges in a global framework that presents new problems and

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demands innovative answers. Solutions that need to be balanced between preservation and socio-economic valorisation, between the territorial government and cultural heritage laws [1]. The issue is highly complex and involves the public administration, the professionals in the sector, the social private associations, and citizens. A question that has already been the subject of great interest (as demonstrated by the countless meetings that have been organized in recent years), but still to be explored in greater depth, even though it is one of the topics that have shaped and characterized the Italian specialist debate during the second half of the 20th century and offered the greatest contribution to international urban planning.

The theme is rooted in ancient times and is connected to the history of architecture and restoration, transcending national borders. It then evolved slowly, within the framework of the constant and perhaps inevitable conflict between ancient and modern, of the contrast between old and new city, between conservation and renewal which has developed – without pause or solution – since the Renaissance [2]. The belief that in reading and narrating the past it is possible to rediscover the foundations for an increasingly dynamic and changing project for the present represents one of the great 'conquests' of modernity [3]. The maturation process towards the defence of the physical integrity of the historic building, its conservation and modification, was in fact the hypotheses of a difficult collective project of European origin, which unfolded and progressed through a series of contradictions and partial findings, as a cultural response to an urban planning problem still largely unresolved, indeed amplified by the violence of global environmental and social emergencies.

Today, we cannot avoid talking about urban regeneration, promoting policies and design strategies not limited to the safeguarding but also attentive to the redevelopment and enhancement of the physical and social heritage of historic cities and smaller historic centres [4]. While the conservation of architectural heritage plays a fundamental role in the development of sustainable territorial policies, for a long time, urban planning has not been able to update its tools, making them finally able to interface and interact between local and national scales, as needed. As other European countries, Italy has not always been able to define sustainable policies, capable of developing 'resilience', in combination between tradition and innovation, for the management of an urban sector affected by sudden and substantial social and economic transformations; integrated and coherent policies and actions, aimed at protecting, first and foremost, the residential use and production functions as indispensable factors for maintaining the identity and character of the places.

Today, market pressures are threatening historic cities with both old and new hazards, and existing regulations are not always able to provide adequate solutions. A widespread trend towards population aging and depopulation, the loss of traditional productive and commercial functions, and, in many cases, serious phenomena of consumption and degradation due to tourism, can be observed. If on the one hand, tourism is "the most important industry of this new century" [5] and therefore an essential factor of growth and development, both at an economic and employment level, on the other hand, it can induce significant negative consequences when the dynamic forces that fuel it are not adequately managed. Over the last thirty years, Italy has witnessed a growth in so-called urban

cultural tourism[1], undoubtedly linked to the process of recovery of the historic centres of cities, the valorisation of cultural heritage and the diversification of cultural activities. A recent study by the National Institute of Statistics (ISTAT) [7] provided an in-depth analysis of this phenomenon, highlighting how cultural tourism represents a fundamental pillar for the tourist attractiveness of the country. Among the eight categories identified, that of "cities with a cultural, historical, artistic and landscape vocation" includes 431 municipalities, distributed mainly in the Central-Northern regions and a little less in the South and on the Islands. Multi-vocation is a factor of tourist attractiveness at a territorial level, especially if cultural, historical, artistic and landscape characteristics are present among the multiple tourist vocations of a territory. According to the latest update of the "Survey on international tourism in Italy - 2022" conducted by the Bank of Italy, 2022 proved to be the year in which cultural holidays and holidays in cities of art were the main motivation holiday for foreigners in Italy [8].

However, the XXVI Edition of the Report on Italian Tourism 2022–2023 highlights that over 70% of international tourists for cultural holidays are concentrated in less than 1% of Italy's territory, i.e. in some areas mainly in the historic centres of a very large number restricted to cities of art, determining serious implications on the sustainability of the impacts of tourism. In this context, tourism appears to be a significant factor that is causing the population reduction and dispersion of large cities [9]. This phenomenon can produce major elements of conflict between the stable and temporary housing dimensions due to the increase in the prices of goods and services and, above all, of the real estate market, the gentrification of the commercial fabric, i.e. the disappearance of neighbourhood shops in favour of large brands and of commercial chains, heavily impacting the environment in terms of pollution and waste management.

The overtourism[2], i.e. that situation in which the impact of tourism exceeds the thresholds of physical, ecological, social, economic, psychological and/or political capacity, can have dangerous consequences in this sense, to the point of threatening the existence of destinations affected or potentially at risk, where tourism development is not adequately managed [12]. Risks that careful planning – based on a real knowledge of that heritage of tangible and intangible values, fabrics, textures, relationships, sensations, shapes, figures, materials, etc. that are inherent in our ancient sites – should be

[1] According to the definition adopted by the UN Tourism General Assembly, at its 22nd session (2017), the term cultural tourism implies "A type of tourism activity in which the visitor's essential motivation is to learn, discover, experience, and consume the tangible and intangible cultural attractions/products in a tourism destination. These attractions/products relate to a set of distinctive material, intellectual, spiritual, and emotional features of a society that encompasses arts and architecture, historical and cultural heritage, culinary heritage, literature, music, creative industries and the living cultures with their lifestyles, value systems, beliefs and traditions" [6].

[2] In 2016, Skift media company specialized in research and marketing in the tourism sector created (and later trademarked) the word 'overtourism' [10]. Several definitions of 'overtourism' have emerged since. According to the United Nations World Tourism Organization (UNWTO), 'overtourism' can be defined as "the impact of tourism on a destination, or parts thereof, that excessively influences perceived quality of life of citizens and/or quality of visitors experiences in a negative way". It is the opposite of 'responsible tourism' which is about using tourism to make better places to live in and better places to visit [11].

able to counteract. Through the case study of Città Alta in Bergamo, "mirror of national demographic dynamics" [13], this paper focuses on this problem, to highlight its multiple aspects, components, problematics, and possible solutions (Fig. 1).



Fig. 1. Bergamo: Lower city and, in the background, the Upper city (@authors).

2 The Upper City of Bergamo: A Valued Historical Centre

The original nucleus of Bergamo is located on a steep hill overlooking the vast plain below. Presumably built by the Ligurians – or more precisely by the Orobii as Pliny the Elder recalls in the third volume of its *Naturalis Historia* –, in 198 B.C., it was ruled by the Roman Empire. In 49 B.C., Caesar granted Roman citizenship to the inhabitants of Bergamo. The town was then re-founded on a regular layout cut orthogonally by two main arteries – the *cardo* and the *decumanus* – and numerous buildings were erected to testify to the presence and greatness of the Empire that will guide it for almost five centuries.

The existence of a fortification to protect the centre, probably dating back to the 1st century B.C., seems to be confirmed by some findings, including an important epigraph which describes the construction of two doors in the mighty surrounding wall [14]. Renovated and consolidated in several parts during the early Middle Ages due to numerous sieges, until the arrival of the Lombards who established a Duchy there in 569, the walls were later partially demolished in 904 when the city was invaded by the Hungarians and restored only later, when civil life moved towards the constitution of the free Municipality. Starting from the 13th century, Bergamo came under the control of the Visconti of Milan who fortified and assigning it the *forma urbis* which it would maintain until the year 1561. This date marked the start of the Venetian Senate's effort to construct a larger set of walls, which still form the monumental bulwark that surrounds the Upper city.

At the same time, if the development of Bergamo Alta remains very limited, the areas of the villages located downstream, along the main commercial and communication

routes, were crowded with new buildings. Between the end of the 15th century and the first half of the 16th century, the city saw its well-being increase thanks to the earnings received from Bergamo residents residing in Venice: greater wealth which inevitably translated into impressive new civil and religious building works [15]. Following the return of Austrian rule, the city experienced a period of great splendour, due to the development of new industrial activities and commerce. Thanks to a more widespread collective comfort, between 1825 and 1845, Bergamo witnessed a new phase of growth in building activity.

In the post-unification era, Bergamo committed itself to the construction of the new city. The urban layout was modernized: the new city centre was planned on the area of the ancient fair – which will be called *Piacentiniano* from the name of its designer, Marcello Piacentini [16] – and new public buildings were erected in the middle and flat areas, replacing those existing in the ancient city. As business, commerce, and administrative life moved to the Lower City, the Upper City was left with its unique and picturesque 'detached' appearance, which is still visible today. The masterplan for the new city of Bergamo was in fact unanimously appreciated, as it guaranteed the intangibility of the ancient one: "whoever wants to rediscover the intact appearance of an ancient Italian city goes up there" will write Roberto Papini celebrating the renewal intentions of the city [17].

As no further expansion was foreseen, in the 1930s a long period was inaugurated in the Upper Town aimed at remedying, through necessary public hygiene works, the state of decay and abandonment of many buildings in the neighbourhood. Luigi Angelini's recovery plan approved 'with honours' in 1934 by the Superior Council of Public Works, managed to implement the theories put forward by Gustavo Giovannoni on urban restoration, so much so that it received applause. Bergamo Alta therefore becomes the manifesto of a certain "sound, well-applied theory" [18], of a new vision of the historic centre that can be preserved and protected through targeted rehabilitation and restoration strategies.

The Angelini's Plan stands out, in fact, for surgical restoration interventions, the pertinent insertion of recognizable modern features, the meticulous study of conservative measures also extended to detailed elements, such as, for example, the signs of the shops. If Angelini carries out some demolition activities 'proper to his time', while opposing to the concept of isolation of the monument, he materializes an important project of urban design which "transcends the rigorous terms of rehabilitation building" [19]. His interventions involve creating new green spaces, designing furnishings and decorations, building stairways to connect existing differences in level, and reorganizing the city fabric, which was gutted by demolition campaigns during the 19th century.

The plan remained in force from 1934 to 1950 and was accompanied by new building interventions such as the construction of terraced houses designed by Giuseppe Pizzigoni, within the framework of the Fanfani Law on subsidized public housing. An intervention certainly to be praised as intended to promote new lifeblood in the ancient fabric, unlike others, such as the transformation that affected the bishop's seminary between 1962 and 1967, causing the almost complete demolition of the underlying historic building fabric and affecting the skyline of the Upper city. In the same period, Bergamo Alta endured a significant exodus of residents towards the suburbs which will cause the neglect of buildings and, therefore, the depreciation of real estate [20].

In the 70s, the weaker social classes were gradually expelled due to building speculation. Moreover, the tourism phenomenon will initiate a significant shift in the centre's liveability. The balance also favoured by the recovery plan of Luig Angelini thus begins to falter and with it that "character of almost continuous life" based on traditional relationships, on "the constant presence of families living in the same houses for long periods, the existence of various kinds of shops that had been operating for many decades [which] made people's acquaintances and almost daily exchanges natural" [21]. In line with the provisions of the general master plan drawn up by Giovanni Astengo and Luigi Dodi in 1969 and approved in 1972, which already included the recovery of the Upper Town among its seven objectives, in 1980 it was proposed by Sandro Angelini, Luigi's son, the *Piano particolareggiato di risanamento conservativo di Città Alta e Borgo Canale di Bergamo* (Detailed plan for the conservative restoration of Città Alta and Borgo Canale). The plan envisaged that, alongside the main function of the residence – also in consideration of the distance from the centre of management activities – vitalising components, such as schools, museums, activities, will be added progressively and without overpowering each other. Cultural and recreational.

Even the *Piano Particolareggiato di Riqualificazione di Città Alta* (Detailed Recovery Plan of Città Alta – PPRCA) edited by the engineer Diego Finazzi and the architect Gianluca Della Mea, with the consultancy of the architect Sergio Crotti in 2005, was based on the idea that the historic centre must play a role propulsive in the territorial context, implying that it would be able to resist the processes of homologation, gender stereotypes, housing standards, functional hybridization: "the upper city is called to claim and promote the differential factors, which represent its true originality and must therefore be protected as unrepeatable values, guaranteed of its unique role in the multipolar territorial system to which it refers" [13]. The PPRCA pursued an enhancement of the historic centre that was conceived not limited to "formulas of mere functionalization and passive conservation, to instead affirm the fertility of modifications, understood as integrations of the existing, in the various forms relevant to the stated objectives […] the historic centre of Bergamo [was] considered the place appointed to play an active and propulsive role within a complex territorial system" [13].

Although many of the excellent intentions pursued by a planning sequence of great importance (summarized here only in part) have produced encouraging results and an overall high resilience of Bergamo to the attacks of globalisation, the historic city in the last fifteen years has undergone great changes and today must manage new conditions, mainly linked to the development of tourism.

3 Tourism in Bergamo: Origins and Developments

The origins of tourism in the Bergamo area are mainly linked to mountain resorts such as Foppolo, Presolana and Selvino which were among the first ski destinations in Northern Italy in the post-war period. Between the 1950s and 1970s, during the economic boom, a process of new construction began in these areas which transformed the Bergamo valleys into holiday resorts and made them the second tourist centre at a regional level, after Milan, in terms of number of visitors [22].

Tourism in Bergamo, however, developed later and not proportionally to the potential of the place, although very precious from a historical-artistic point of view as well as

rich in traditions with deep roots. This was due to the strong industrial vocation linked to the tertiary sector of the city and its hinterland which did not initially consider tourism as a primary factor for local economic growth. The profound identity value and the attachment of the people of Bergamo to their historic centre have led them to consider *extra moenia* presences as a threat to a stability which, in a context of multiculturalism, would have been altered [23, 24]. The opening of the town to massive tourism is a recent event that is closely linked to the profound cultural, social, and economic changes of the new millennium. The locations that had attracted most flows in the past, such as mountain areas, had over time lost their attractiveness, and consequently their competitiveness, due to growing antagonism between destinations – even distant ones – that were now easily reachable and with a greater number of services at lower costs. Ineffective coordination between the public and private sectors was common in regional policies in the tourism sector until the 1990s, with few and sporadic initiatives often organized in a rented and independent-managed context.

A first change occurred with the creation, in 1997, of the Consortium for Tourist Promotion of the Bergamo area (today, the Agency for the Development and Tourist Promotion of the Province of Bergamo): a coordination body between the administrative institutions, the private sector and the small operators, aimed at promoting the potential of the Orobic province [25]. The aim was to convey the image of Bergamo as a city of Art and Culture, like Rome, Milan, Venice, Florence, and Naples. This marked the beginning of the season of major exhibitions which opened in 1998 with the event "Lorenzo Lotto: the restless genius of the Renaissance", which had 165,000 visitors and great critical success. In 2000, the exhibition "Caravaggio, light in Lombard painting" dedicated to the Bergamo painter Michelangelo Merisi was inaugurated and, a little later, the monographic exhibition "The Still Lifes of Evaristo Baschenis: the Music of Silence" was even exhibited at Metropolitan Museum of Art [26]. According to the Tourism Observatory of the Province of Bergamo, visitors to the city increased from less than 150,000 in 1992–2002 to over 550,000 in the decade 2002–2012.

At the same time, at a regional level, the project "UNESCO Sites: Leonardo's itineraries and tourist-cultural excellence" was launched with the aim of promoting knowledge of the then existing World Heritage sites. Lombardy was the region with the largest number of recognized sites (nine of the forty-seven in total on the national territory, today eleven out of fifty-nine) and Bergamo, with its 'Upper city and villages' was included in the Tentative List in 2006. The candidacy was not approved but the failure led, in 2012, to the establishment of the Terra di San Marco association to support a new proposal, this time contextualized in the more specific framework of the Venetian fortresses and within a serial site including eleven locations between Italy, Croatia and Montenegro. Expo Milano 2015 saw a significant process of internationalization and a significant increase in tourist flows. The great event, in addition to improving the image of the entire Region – associated with the concepts of development, progress and modernity – allowed a redevelopment process for Bergamo, first territorial and then urban, still underway.

The creation of new road infrastructures and the expansion of Orio al Serio airport – since 2014 the third most important airport, after Rome Fiumicino and Milan Malpensa, both for passenger traffic and for freight traffic – have made the city the 'Gateway to

Italy' giving it a strategic role within the network of connections between the peninsula and the rest of Europe. The city has been able to attract tourists thanks to this, but there are now actions needed to keep visitors and not denigrate Bergamo as just a transit spot.

4 The Caravaggio Airport and the Tourism Boom

The strong growth of air transport at the end of the last century and the nearby presence of the Caravaggio international airport of Orio al Serio, placed Bergamo at the centre of the north-western Italian infrastructural connection system. The city, previously only affected by road traffic along the route between Venice and Milan, has become, in a few years, the main access hub of the integrated connection network (air, road and rail) of Lombardy-Veneto. The airport's rapid growth has led to new economic development and renewed tourist demand, resulting in a profound transformation of both peripheral areas and the historic centre.

The Bergamo airport was built in 1939 for military purposes, at the same time as Hitler's armed invasion of Germany against Poland. Its conversion into a civil airport took place at the beginning of 1970, as a secondary landing strip for Milan Linate. Its traffic, limited to a few destinations, mostly national, has been the pretext several times for a possible closure, which fortunately never occurred. In the following 90s, the opening of a hub for freight traffic (chosen by DHL, UPS, and Lufthansa Cargo as their sorting centre for Southern Europe) favoured the relaunch of the air station; however, the strong increase in passengers will be determined by some low-cost airlines who will choose it as their main base in Italy (Fig. 2).

The Caravaggio airport was the driving force of the economic development of the entire Bergamo area, especially in the period of strong financial crisis following 2008. Tourism development has made it possible to stem the recession in the craft, commerce, and industry sectors. The city of Bergamo, interested in previous years by small flows restricted to business tourism, limited to the lower city, has therefore readjusted its structures to welcome an increasingly higher number of visitors. A late and forced development which also involved the Upper Town, which until then had received little attention from visitors who were not very interested in the artistic and cultural heritage of the ancient settlement. A process that was more immediate than desired, given the socio-cultural profile of the Bergamo citizen, strongly attached to traditions, and disinclined to accept 'external visitors' because they would potentially disturb the existential balance and/or because considered a possible threat for their own traditions.

Despite everything, the inhabitants have altered their habits and adjusted their houses, particularly in the Upper Town, to establish new lodging structures that were not present before. Until a few years ago, the historic city was devoid of hotels and the new ones recently built, of the extra-luxury category, are aimed at welcoming a certain niche market, which is however a minority in the context of presences in the city. Non-hotel accommodations were enhanced by the creation of bed and breakfast, or the renovation of large, elegant apartments divided into smaller real estate units for rental purposes. A necessity dictated both by the growing demand for temporary lodging for travellers, and by the opportunity to guarantee profits to residents, even though it may force them to move to other areas of the city.

Bergamo is today interested in leisure and cultural tourism which is characterized by a low average stay of tourists, in many cases daily, which has significantly decreased after the recognition of the Venetian Walls as a UNESCO site. In fact, the number of visitors – mainly national, although there is an increase in foreign presences – who stay in the city for only a few hours and 'spending little money' has raised [28].



Fig. 2. The "Caravaggio" airport in Orio al Serio, serving the city of Bergamo (@authors).

The inclusion of the fortified system on the World Heritage List has, in fact, led to a worrying enhance in the attractiveness of the Upper city, which is now almost unsustainable. Safeguarding policies must be able to govern the phenomenon to avoid the danger of the site being subjected to further transformation for tourist use (hotels, restaurants, or new garages) which could lead to the irreparable loss of its identity (Fig. 3).

5 The Adaptive Reuse of the Upper Town

The sustainability of the Upper Town has been significantly impacted by the recent surge in tourists. Here too, the past is exploited for economic purposes. Traveling has been transformed into a predatory animal by the advancement of transportation and communication technologies. Bed and breakfasts, apartments for rent for tourist use, or short-term rentals are replacing homes more and more because of regulatory ease in changing the intended use of property. A transformation that now appears irreversible, both due to the growing flows of visitors and a trend in the real estate market dominated by a strong demand for short-term accommodation, not for residential homes. The advent of the new digital tourist platforms, which have made rental negotiations quick and simple, has transformed the historic centre into a large widespread hotel which, to attract, needs to crystallize its image by making it an open museum. The city has become a work of art, with visitors enjoying it as a work of art to capitalize on its historical charm. It has become a sort of luxury dormitory for privileged tourists, then transforming the resident or common user into an increasing rarity [29].

Bergamo, the city of art, has therefore once again 'repudiated' the inhabitants of the most economically fragile groups – the new and the older generations, encouraged (or



Fig. 3. Bergamo Alta invaded by the tourists (@authors).

forced?) to give up their homes –, profoundly changing the social fabric. The reuse of the city has transformed the ancient spaces into hospitality structures and generated new activities with commercial typologies essentially useful to visitors (take-away pizzerias, ice cream parlours, craft breweries, etc.) and, again, in vintage shops and trendy bars, to the detriment of artisan shops and necessities aimed at satisfying the needs of the inhabitants. It is an eclectic panorama, almost devoid of character and memory, that assimilates it to other Italian towns [30, 31]. The new shops are, in fact, alien to the soul of the historic centre and the few historic premises remaining – such as the Caffè del Tasso or the Pasticceria Cavour – have been partly deprived of their essence and made a tourist icon designed to celebrate the memory of the past.

The function performed by neighbourhood businesses is fundamental for the sustainability of the weakest social fabric, the elderly for example for whom the hardship is increased by not having their own means of transport. A few years ago, the last shoemaker closed its doors (in 1976 there were five), the surviving food and/or fruit and vegetable shops are only three, transformed into retailers of luxury goods outside the area or supermarkets whose goods on display are mainly those that the passing guest might need. L'Alimentari is the name of a commercial activity in Piazza Vecchia which, although selling cured meat, cheese, and local products to take away, is essentially a restaurant that is too expensive for most people. Bakeries are places that basically sell slices of pizza rather than bread and it is no longer possible, within the walls, to find a plumber, a mechanic, an electrician, or a painter. If a resolution of the City Council of

December 2017[3] defined a new regulation to safeguard the *décor* in the areas of historical interest in the Upper Town, prohibiting the opening of some types of commercial establishments – fast food, self-service, sex shops and massage centres – this has not prevented some trendy or clearly tourism-oriented substitutions.

The neighbourhood seems, in fact, to have definitively taken on the appearance of a luxury district for the wealthy classes only, to the detriment of its popular dimension; an analysis based on demographic trend data which highlights how the population residing within the walls is made up of fewer 'historical inhabitants' and more 'foreign' healthy people that decided to invest in the Upper city, solely for speculative purposes or to spend the weekend.

Some places, once emblematic, such as the ancient Il Giardinetto restaurant – with the characteristic pergola and the bowling green designed by Luigi Angelini – located in the historic Piazza Lorenzo Mascheroni previously known as Piazza Nova, today experience a new season thanks to their reuse in a tourist key. Over the last thirty years, the old restaurant has become the San Lorenzo hotel. Once a small structure, in 2019, it has undergone a major expansion and renovation to become a luxurious 5-star hotel. The area of intervention is essentially an archaeological site, a garden next to the Chiesa del Carmine, on whose land lie, like the members of a decomposed body, the fragments of historical architectures that have overlapped through time, from the 6th century B.C. to the late Republican era, from the Middle Ages to the Renaissance. The works revealed a portion of the Roman city and the architect decided to free the ruins from the earth, by isolating them like an archaeologist in an excavation. They then obtained a basement at the garden level, to host the breakfast room, the SPA, a meeting room, services, on which the new project is based: a new body is superimposed to the fragments of the past, in the aim of giving them back dignity and restoring a sense of memory. However, this place is no accessible to everyone, but has become the extraordinary setting for the gourmet restaurant Hostaria. Nevertheless, the case of Sant'Agata former prison, for many years forgotten and neglected, has had a different fate, demonstrating a trend that is fortunately increasingly widespread. Founded on ancient defensive walls from the 10th century, it became a monastery of the Theatine fathers in the 17th century. Converted into a house of detention from 1802 until its definitive suppression in the 1990s, it is today owned by the Municipality. The Maite Social Promotion Association, which was founded in 2010 by a group of friends with the purpose of encouraging cultural, social, musical, theatrical, food, and wine events in the city of Bergamo is taking care and using its spaces. The project, which rests on solid roots, has taken on an increasingly intergenerational character, collecting adhesions both among young people (with a creative, playful, and proactive role), and between adults (who use space as a place of aggregation in its more classical conception) given the articulated and diversified programming. The association has always dreamed of restoring this location to offer new services to the city, but there has been a dearth of funds and investors. The city has been involved in a long debate over the transformation of the structure into a new luxury hotel in recent years, but luckily, the municipal administration did not find a consensus on this path. In recent times, a

[3] This provision was legitimized by the legislative decree no. 222 of 25 November 2016, which allows mayors to intervene to regulate commercial activities, meaning product categories, within particularly delicate situations from an environmental, monumental, and artistic point of view.

project was approved that will allow the complex to be used for social housing, while providing for the maintenance of cultural spaces and the creation of a prison museum to safeguard the value of testimony. Thanks to PNRR funds, 15 apartments will therefore be built, mostly studios, with subsidized rent, and intended, preferably, for young people and couples.

6 The New Strategies Implemented by the Municipality and Local Actors for the Sustainable Valorisation of Upper Town

Bergamo's historic centre is under threat, just like many other cities of art. It is fighting against the consequences of a dangerous trend towards museumification, which risks turning it into a picturesque location that is popular with tourists but not with residents. We can observe a certain drift towards market demands, towards the spectacularization of its rich history and stunning architecture, but mostly for economic purposes. Its community is always looking for strategies and tools to ensure its genuine vitality. In this sense, the Association for the Upper Town and the Hills is battling to prevent its transformation into an element that is alien to its origins and context.

Salvatore Settis reminds us that if Venice ever dies, it will be above all due to the oblivion of itself, because every city "is a living narration of its own history, but also the face and translation in stone of the people who inhabit it, preserve it and transform it" [9, 32]. Venice therefore represents the archetype of the destiny of many historic Italian cities which are emptied of their inhabitants and their intrinsic peculiarities to flatten themselves on a standardized modernity, reducing them to a mere tourist-hotel function. And, in this sense, Bergamo's Upper Town also runs the risk of being annihilated by that monoculture of tourism that enriches a few, impoverishes many, and destroys urbanity. For some time, many have underlined the usefulness of bringing families made up of young couples, children, and elderly people back to the Upper Town and thus recovering that lost dimension of simple conviviality and equally 'normality'.

The hypothesis that receptive use is unfairly competing with classic residence is confirmed by incontrovertible statistical data. The impossibility of attracting the middle-lower classes to encourage the necessary social turnover, at the same time, favours the obsolescence of homes, if not their total abandonment, resulting in a large presence of disused buildings, both public and private. Numerous prominent city figures have accused tourism of being the cause of the depopulation of the ancient, fortified village but perhaps few ask themselves whether ordinary people still want to live in the Upper Town; if they want to live in a city profoundly different from the most recent expansions, certainly more picturesque but infinitely less practical, or if they want to live in properties which, due to size and finishes, are far removed from the comforts of modern homes. And again, is it true that these 'replacement' activities – recent but now prevalent – are of no benefit to the local community?

The most recent activities related to tourism are perhaps not only something to be condemned but deserve to be further regulated; to be included in a flow control and coordination plan aimed at the regeneration of the ancient village aimed at counteracting its isolation, based on continuous and proactive assumptions over time. A plan which, based on an accurate knowledge of the place, does not cancel the present nor the past

but which allows, through appropriate rebalancing actions, to ferry the Upper Town towards a more conscious and evolved future. The policies developed out by the current administration goes in this direction: preventing the depopulation and distortion of the Upper Town, through the construction of a network of relationships between subjects of different nature, which places culture at the centre of every reflection. Culture defines the identity of a city and its community, has a strong social and economic dimension and is therefore an essential element in the processes of urban development and regeneration.

A work that goes hand in hand with the effort made by the local University, which was founded in 1968 and settled in the Upper Town precisely to become an engine of development, and has gradually broadened its horizons, confirming its presence in the ancient centre: from the first headquarters in Piazza Vecchia, in the Palazzo del Podestà which dominates the main square of Città Alta, to the locations in via dei Caniana, Sant'Agostino, via Pignolo, which radiate the university into the city and make up a system of campuses. The Aula Magna of the university is none other than the former Church of Sant'Agostino, the first architectural element, dating back to the 13th century, that you encounter upon arriving in the Upper Town and skirting the Venetian walls.

Together with the aforementioned project for Sant'Agata, it is worth remembering the "Housing first" social inclusion project of the Municipality of Bergamo, which for the hospitality of people in conditions of serious marginalization, reserved five apartments owned by the municipal administration in Città Alta, (three of the premises are located along via Gombito, one in via Porta Dipinta and the last in via Solata). The choice of the municipal administration aims to strengthen the social mix of the historic centre, in which the municipal houses are destined to have a fundamental role. In the Upper Town, 103 families currently live in properties owned by the Municipality of Bergamo, for a total of 164 people. In addition to those in "Housing first", another five apartments are being assigned for next year, thus offering a further contribution to a process of support and social reintegration.

Another advantageous example of culturally based regeneration is that concerning the former Carmine convent. The complex, built in the second half of the 1300s, was long ignored and in a state of abandonment. It was restored by the municipal administration in the years 2010–2013. Since 2015, work has begun to reopen the covered access to the monastic complex, finally revealing to the city a monument which had remained close for more than fifty years. Between 2015 and 2016 the Tascabile Theatre of Bergamo (TTB), in collaboration with the municipal administration, gave life to the project of cultural recovery and valorisation of the Monastery, starting from the idea that the value of the Carmine is not constituted only by its material data, but also by the set of immaterial characteristics that characterize it and identify it culturally. Over the course of its long stay at Carmine, the TTB has fully integrated with the place, with its history, its nature, its peculiar privacy, dedicating time, and care to make it correspond to the common vision of the city: that of space to be dedicated to art and culture.

Since 2015 the cloister has been home to the international and multidisciplinary summer festival "Arcate d'arte" (consonances of theatre, culture, and art). Its activities are composed and organized for an open square model, a catalyst element within the life context of the Upper Town capable of producing political, educational, and artistic involvement of citizens. That of Carmine can be considered a successful model because

it was based on the idea that the new functions to be assigned to the building could be the answer to citizens' needs. The building has actually become a link between space and community: an innovative public-private partnership that has produced a concrete and tangible regeneration of the urban fabric.

These activities are fully included in the provision of new *Piano di Governo del Territorio* (territorial government plan – PGT) adopted by the Municipality of Bergamo with resolution of the Municipal Council n. 59 of 16 October 2023. The PGT collects the objectives to be achieved in the municipal area in three themes: Attractive Bergamo, Sustainable Bergamo, Inclusive Bergamo. These are the strategic lines from which planning for the city's future begins, translating into rules, a vision which, also and above all for the Upper city, sees culture and beauty as a driving element.

7 Bergamo Brescia Italian Capital of Culture 2023

The idea that culture is a driving force for the development of European identity, capable of increasing citizens' sense of belonging to a single large community "state", matured in Europe at the beginning of the 80s of the last century. On June 3, 1985, the European Commission designated Athens as the initial 'European City of Culture' to honour Greek minister Melina Mercouri who started the initiative. A fund was set up in the EU budget to finance the organization of annual events aimed at strengthening both the international image of a united Europe and the relations between EU countries. Every year, from 1985 to 1999, a remarkably deserving city was chosen as the venue for the event to enhance the historical and artistic heritage and cultural traditions of a particular region. The formula remained unchanged until 2000 when a shift rule was introduced to ensure visibility for each country, and the designated locations were increased to two (they were called 'Capitals' instead of 'Cities'). The title was first granted to Florence in 1986, followed by Bologna in 2000, Genoa in 2004, and Matera in 2019.

The Minister of Cultural Heritage, Dario Franceschini, in 2015 – on the presentation of candidacies for the 2019 European Capital of Culture won by the city of Matera – established the 'Italian Capital of Culture'. A national declination, already in place in other countries, of the prestigious European title. The five cities that did not reach the European goal (Ravenna, Siena, Cagliari, Lecce, and Perugia) were the first Italian capitals; then Mantua in 2016, Pistoia in 2017, Palermo in 2018, Parma in 2020 (postponed in 2021 due to the pandemic), Procida in 2022, Bergamo and Brescia in 2023. The title will go to Pesaro in 2024, Agrigento in 2025 and L'Aquila in 2026 (in 2019 the award was not given).

Eight years after the program's launch, the General Secretariat of the Ministry of Culture has initiated a study to examine the effects on the territories of the winning cities. Cultural interventions' impact was evaluated using methods that measured cultural participation, social and economic development, and event management policies, both during and after. The first results, which were recently published in a synthesis report, will serve as the basis for new guidelines for constructing future projects (Fig. 4). The document demonstrates that even with the significant efforts made by individual cities, the long-term outcomes have not always been satisfactory [33]. The annual appointment inflates the title and reduces the time needed to prepare a program that cannot just be a

list of events, but a strategic plan capable of initiating processes of change in the long term.

For the purpose of this study, it appears necessary to focus specifically on the Bergamo Brescia Italian Capital of Culture 2023 project, that was born in July 2020 during the dramatic COVID-19 pandemic, with the aim of giving a sign of hope and relaunching. A necessary moment of beauty to believe in a possible rebirth through the conscious choice to invest in culture. The project was a recognition of Bergamo's historic, artistic, and cultural heritage, as well as a testament to the capacity of a place to revitalize and plan for the future. A few months after its conclusion, the economic impact analysis is indicating a positive outcome of the event. The Upper city of Bergamo has hosted over a million visitors with an increase in the hotel sector of 29.5% and in the non-hotel sector (bed and breakfasts, holiday homes and tourist rentals) of even 53.2%. Very high numbers but, unfortunately, characterized by a very low average value of overnight stays/arrivals (only 1,8): an indicator of very short and concentrated stays during public holidays and weekends. These are unflattering values for the surrounding territory with an increase much lower than expected due, perhaps, to a lack of extra-urban public transport. Even the spending of each tourist, concentrated mostly in Bergamo Alta and in the city centre, although it increased in percentage, was much less than the increase in attendance; the rise in costs, and therefore in prices, has led to a general reduction in consumption in shops, clubs and restaurants, typical characteristics of mass low-cost tourism [34].

However, from a social and cultural impact the results were excellent thanks to the project's ability to reconcile important events with the small activities carried out by cultural businesses in the area. The major events attracted large numbers and allowed the city's brand to be launched. Many of them have made it possible to give continuity to already existing projects, such as the exhibition "The Walls in History: treasures of a Renaissance fortress city", which with 45,000 visitors, narrated the construction of the Walls from its origins. The exhibition was one of the stages of "PanoramaMura", a project of the Municipality of Bergamo which since 2018 has been dealing with the valorisation of the UNESCO title to build widespread awareness of the role of Bergamo within the defensive system of the Republic of Venice.

The local communities expressed their specificities through bottom-up activities that were embodied by the history and personality of this place through small events. Participatory planning allowed local realities to tell their story and enhance themselves within a single large container, making events possible [35].

The creation of shared transversal actions and the establishment of a coordination network between institutions and cultural operators (associations, non-profit organizations, etc.) represented the most innovative aspect. There was unanimous recognition of the good quality of the events, their ability to be widespread and involve different audiences, and their joint coordination of a broad and varied cultural offering. But some critical issues were linked to large events in the need to also include trashier proposals to have the squares full of people and provide an image of the city as alive and internationalized with a commodification of culture to the advantage of 'lesser quality' tourism: globalization dynamics that made it possible to finance the program, but which are not sustainable in environmental, sustainability and public health terms.

The challenge is now to keep the network of cultural actors active in the long term so that it would be sustainable and of high quality, focusing on smaller actions aimed at a cultured and local public capable of impacting the lives of people with consistency over time and improving their quality of life.

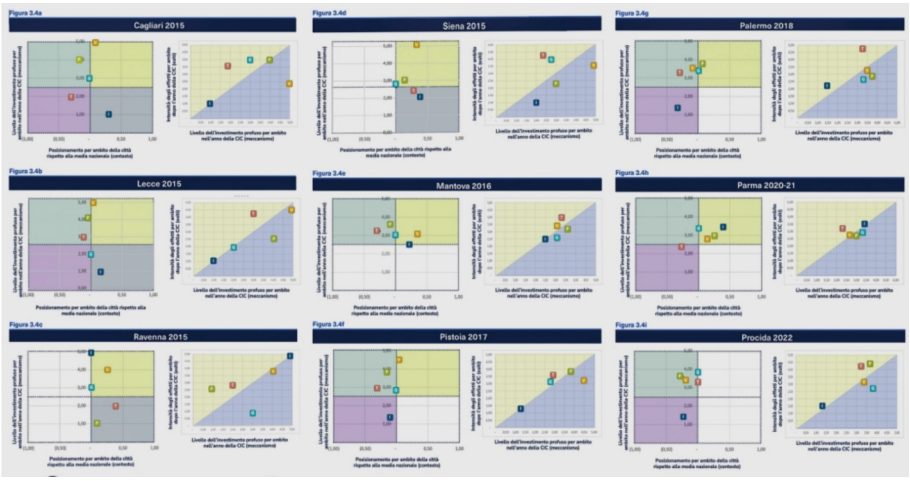

Fig. 4. Impact analysis of cultural development for the Italian Capitals of Culture 2015–22 [33].

8 Conclusions

The Upper city of Bergamo, thanks to an exceptional cultural heritage and a series of favourable infrastructural contingencies, has transformed in a few years into one of the great Italian destinations for cultural tourism. This has created a series of problems typical of the cities of art, subject to phenomena of congestion and loss of identity, that have required the establishment of policies and measures to address visitors' growth without negatively impacting on both the identity of place and the life of its inhabitants or causing the destruction of the physical, economic, and sociocultural environment.

Historic-artistic monuments and buildings alone are not sufficient to constitute a tourist attraction, but to become such they must be accompanied by an attribution of meanings that makes them authentic and unique in the eyes of the visitor [36]. To allow tourism to truly represent a sustainable resource over time and not a destructive weapon, it is necessary to implement strategies aimed at establishing a correct and balanced interaction between residents and tourists, to develop the city to fit with the residents' needs and desires, to regularly monitor the perception of local communities towards tourism and promote the value of the sector among residents.

In this sense, the Municipality of Bergamo has focused on culture and beauty, building over the years, virtuous partnerships between public bodies and private entities for the management of spaces and the assignment of resources, aimed at preventing important

transformations of the social fabric of its ancient historic centre and making it grow in terms of relationships and well-being, together with (and not despite) tourism.

The latest statistics on the number of residents appear to be comforting: Città Alta is slowing down depopulation and will stand at 2691 inhabitants in 2023, 74 more than the previous year. A trend that we hope will remain unchanged over time and that will also see it flourish again in the Upper town, the *beauté de l'ordinaire*!

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Territorial Dynamics and Community Resilience: Transient Housing in Post-earthquake in Al Haouz Rural Regions in Morocco

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Abstract. The integrative strategies for transient housing related to vulnerable rural communities in Morocco, in the aftermath of the recent earthquake, introduces their unique organization and lifestyle. Adopting a field-oriented approach, this study embraces a descriptive-analytical method with a focus on field-survey and post-occupancy-evaluation. The criteria for understanding the adaptive territorial dynamics of transient housing are derived from on-site investigation. Field-research was mainly conducted in the earthquake-affected villages in the Al Haouz region at the south of Marrakech, villages of Asni, Tlet Nyaakoub, Tizi Ouadou and Tafghaght. While drawing insights from community engagement, questionnaires, and spatial observations, sets of criteria are categorized through socio-cultural, physical-functional, and technical-structural elements. This research reveals, accordingly, key insights into the adaptive measures taken by rural communities, who proved indeed tactical patterns of resilience and resourcefulness in their transient housing typologies that are genuinely exposing their local topographies and territories. This study identifies, henceforth, sites, where communities have set temporary housing forms that derive out of their sociocultural context. This demonstrates their local capacity in facing challenges through resilient adaptation processes. Research findings would contribute to developing a strategic emergency territorial planning framework, emphasizing spatial considerations, community engagement, and the preservation of cultural practices as rooted resilient savoir-faire. The purpose of paper is to shed light on the relevancy of local know-how of vulnerable rural communities that have their genius-loci to urgently solve consequences of natural catastrophes. In addition, these findings prove that rurality is not limiting but capitalizes accumulative frugal innovations that ought to be considered once dealing with resilience and sustainability. The local rural communal tactful actions to deal with emergencies are hence to be further researched to set more advanced strategies of transient housing in the global scale.

Keywords: Transient housing · Rural Resilience · Territorial Planning · Communal Adaptation

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1 Introduction

Earthquakes, pervasive natural disasters, continue to expose the heightened vulnerability of human settlements worldwide [1, 2]. Globally, yearly statistics are alarming (Table 1). Earthquakes influence settlement organization and evolution by disrupting infrastructure [3, 4], causing damage to buildings [5–7], and socioeconomic patterns [8–10]. To reduce earthquake impact, high seismic activity regions require strict building codes, advanced early warning systems, and recovery strategies [11]. Conversely, areas with lower seismic activity frequently lack preparedness, leading to higher vulnerability. Recognizing the need for tailored solutions is crucial for all nations, irrespective of seismic activity levels, to minimize earthquake risks, and to dilute post disaster impact.

Table 1. Average of earthquakes happening in the word per year

Number per year	magnitude	characteristics
20,000	2.5 or higher	Vast majority of these are small and go unnoticed
1,300	5.0 or higher	More likely to be felt by people
10 to 20	7.0 or higher	High impact

Source: Global Seismographic Network and International Seismological Centre

Morocco's seismic vulnerability was made evident by the September 2023 earthquake, which shook the country's rural infrastructure. The quake's impact on shelter and housing was widespread, with Marrakech's densely populated areas and the Atlas Mountains' rural villages suffering severe damage. According to the Global Disaster Alert and Coordination System (GDACS), the disaster exposed approximately 320,000 people to high-level seismic activity [12]. The villages in the High Atlas, close to the quake's epicenter, suffered significant losses. Some communities have reported fatalities that exceed 50% of their residents, leaving them in desperate need of assistance and strong recovery plans. The affected communities, typically characterized by structural building flaws and limited access to emergency services, faced additional challenges. This vulnerability permeated beyond the immediate aftermath, infiltrating the complex spatial weave of these communities. Despite these challenges, Morocco's rural settlements demonstrate remarkable resilience, bolstered by a strong sense of community and a wealth of localized knowledge, including a thorough understanding of the land and traditional construction methods.

The interplay between strategic planning and cultural preservation becomes apparent as the study explores transient habitations—a critical aspect of post-earthquake recovery. Often, these habitations are deftly adapted to align with the community's lifestyle and cultural preferences, thus integrating into the post-seismic fabric of rural life. Despite the clear need to understand these dynamics, research remains scant, particularly on the adaptive territorial dynamics of transient housing within rural Moroccan contexts.

This study investigates the adaptive strategies used by these communities in response to seismic adversities, through a spatial planning lens that considers seismic resilience, infrastructure robustness, and community preparedness. Our research seeks to close this

gap by providing a nuanced look at resilience, resourcefulness, and encountered challenges, thereby contributing to a strategic emergency planning framework that addresses the unique needs of earthquake-affected rural villages.

This paper's structure is divided into sections, each of which builds on the previous one to form a cohesive narrative. Following the introduction, Sect. 2 describes how we chose our case studies and conducted our research, laying the groundwork for the mixed-method approach. Section 3 summarizes our findings, describing the various transient housing strategies used by the communities. The discussion in Sect. 4 places these strategies in the context of global post-disaster responses, providing a comparative analysis. We conclude with a synthesis of our findings, advocating for strategic and culturally informed emergency planning as critical to the resilience of rural communities in the face of natural disasters (Fig. 1).

2 Case Study and Methods

2.1 Sample Villages Selection

Following the September 23rd earthquake south of Marrakech, Morocco, over 2930 villages were affected to varying degrees. This study focuses on the rural communities that bore the brunt of the earthquake, with representative samples drawn from the Al Haouz region, which suffered extensive damage. Using a random sampling methodology, we chose four villages (Table 2) that represent the range of affected areas: Asni, Tlet N'yaakoub, Tizi Ouadou and Tafghaghte. Because of their different geographies and sizes, the chosen villages provide a diverse perspective on the earthquake's effects. Figure 2 depicts the geographical distribution of these villages, laying the groundwork for future research into their transient housing initiatives and population adaptability.

Table 2. Selected villages

	Village	Population	Rural Commune
Communal Center	2.5 or higher	394	Tlet N'yaakoub
	5.0 or higher	694	Asni
Peripheral village	Tizi Ouadou	292	Ouazkita
	Tafghaght	739	Amaghrass

Source: HCP Morocco, Population Census 2014

2.2 Data Collection and Analysis Methods

To comprehensively assess the adaptive territorial dynamics of transient housing, our study employed a mixed-method approach. This involved descriptive-analytical procedures, underpinned by field research and post-implementation evaluation techniques.

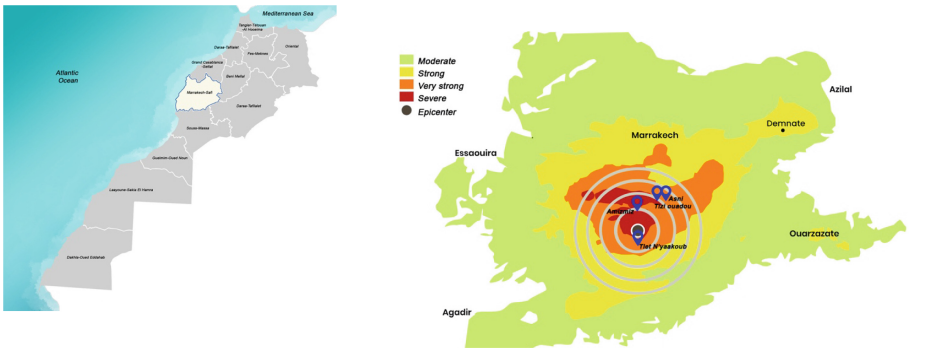

Fig. 1. Maps showing the regions impacted by the September 8 earthquake and the locations of selected villages. Source: United States Geological Survey

Survey and Questionnaire Design

The survey instruments were meticulously crafted to capture a wide range of socio-cultural, physical-functional, and technical-structural variables. Questions were structured to elicit both quantitative data, such as household sizes and material preferences, and qualitative insights into community resilience and resourcefulness. Demographic questions were included to ensure a representative cross-section of the affected populations, with particular attention to age, gender, occupation, and family structure.

Post-implementation Evaluation Techniques

The post-implementation evaluation was based on systematic observations and a tailored set of criteria to assess the effectiveness and adaptability of transient housing solutions. These criteria were developed using existing literature and refined during preliminary field visits. They included aspects such as spatial flexibility, cultural adequacy, material durability, and ease of construction and disassembly.

Field Research Methodology

The field research component involved visiting the selected villages, engaging with the local communities, and conducting spatial analysis of the erected transient housing structures. We utilized geolocation techniques to map the distribution and arrangement of these structures, while satellite imagery provided a macro-scale perspective on spatial organization and the extent of earthquake damage.

3 Results

3.1 Spatial Analysis of Transient Housing Initiatives

The provision of tents was a primary form of transient housing, offering quick deployment and a private haven for families amid the turmoil. Although the uniform design of the tents facilitated rapid distribution, they often fell short in the harsh environmental conditions prevalent in the region and did not fully accommodate the longer-term spatial needs of the residents. A deeper spatial analysis revealed that, while these shelters

provided initial relief, they lacked the flexibility to adapt to the varied and evolving requirements of households over time. Confronted with these limitations, local communities took proactive measures to modify and arrange the tents to better suit their needs. Leveraging an innate understanding of the landscape and their daily routines, families adjusted the placement and orientation of tents to shield against weather extremes, maximize shade, and maintain airflow. Inside, spaces were reorganized or combined to preserve familial bonds and accommodate multi-generational living, a common cultural practice in the region. Some residents expanded their living areas by connecting tents or building additional makeshift structures, thus creating compound-like arrangements that emulated the private courtyards central to their pre-disaster lifestyle. These spatial adaptations by the locals not only improved their immediate living conditions but also signaled the importance of incorporating flexibility and cultural sensitivity into the design of transient housing solutions (Fig. 3).

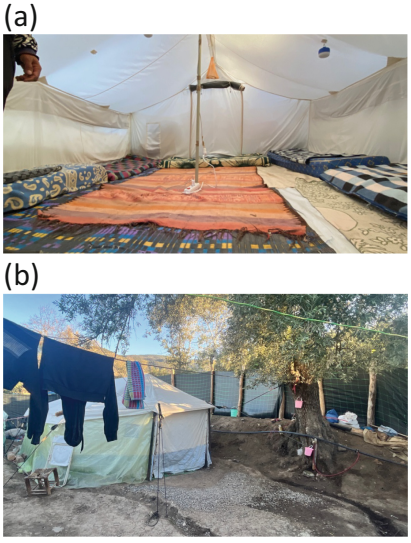

Fig. 2. (a) the inside of a transient housing unit; (b) the outside of the housing unit in Tafeghaght. Source: Authors on site pictures

As a shift from isolated tents to more integrated communal clusters marked a significant evolution in transient housing within certain communities. These clusters, a collective of tents and temporary structures, were meticulously arranged to create a shared living environment, promoting a sense of unity and organization amid the chaos. Such configurations varied from rectilinear patterns, which maximized efficiency and ease of access, to more organic layouts that conformed to the contours of the site and the residents' existing lifestyle and daily activities.

Rectilinear clusters were often seen in areas where the terrain permitted systematic planning, allowing for clear delineation of shared facilities like bathrooms, and communal gathering spots. This structured approach facilitated efficient resource distribution and a semblance of normalcy in day-to-day life. In contrast, in areas with uneven terrain

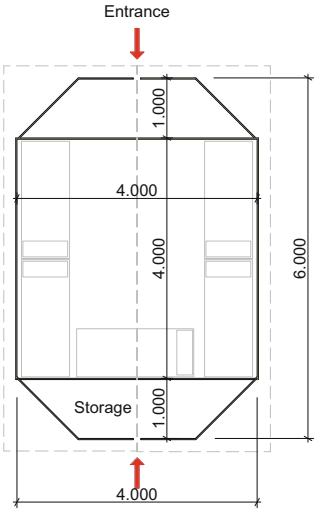

Fig. 3. Plan of transient housing unit. Source: Authors

or where residents' routines were closely tied to the landscape, clusters took on a more spontaneous arrangement. Here, the placement of tents was guided by the need for proximity to farmlands or water sources, preserving the rhythms of rural life and agricultural activities.

In both scenarios, the clusters were living systems, continually adapted by their inhabitants. Residents personalized these spaces, adding partitions or extensions, to recreate the familiar sense of home and maintain privacy. Communal areas evolved, reflecting the social fabric of the community, where shared spaces became focal points for interaction, support, and the rebuilding of community resilience. This dynamic adaptation of clusters reveals the importance of adaptable design principles in transient housing, catering to the diverse needs and preferences of disaster-affected populations.

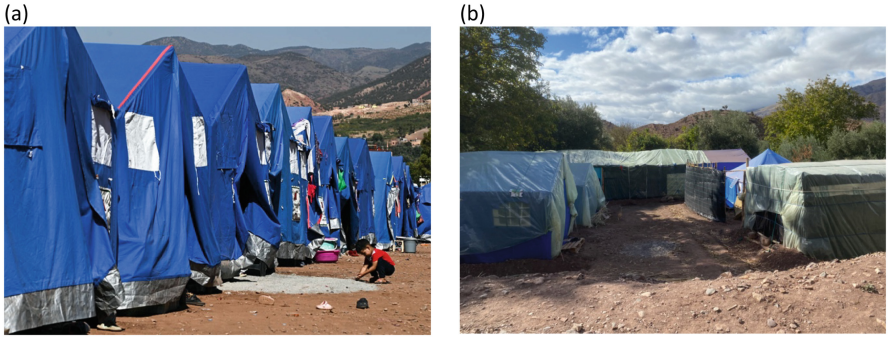

Fig. 4. (a) rectilinear layout cluster; (b) organic layout cluster. Source: (a) Maghreb Arab Presse; (b) Authors on site pictures

Communal Centers

Asni and Tlate Nyaakoub rapidly galvanized their social fabric into cohesive transient housing clusters, leveraging their plane topography, and pre-existing parcel structures to facilitate the inclusive implementation of tent camps. Demographic surveys underscored the effectiveness of this strategy in areas, where the arrangement of communal living spaces was inherently aligned with the residents' preference for close-knit family units. Tlate Nyaakoub demonstrated a remarkable use of its compact layout to enhance resource sharing and maintain vital support networks (Fig. 5). Strategic placement along main roads and rivers allowed for the swift establishment of emergency structures that served public facilities and commercial functions, thus accelerating the rehabilitation of the initial roles these commune centers played in local life. This spatial organization not only provided immediate shelter but also ensured the preservation of community routines, social interactions, and the overall integrity of daily life amidst recovery efforts.

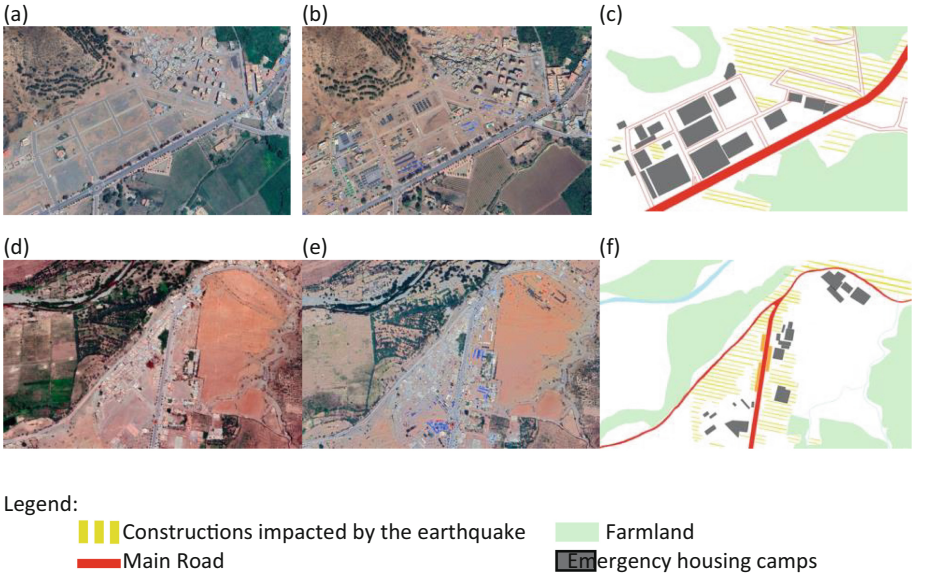

Fig. 5. (a) Satellite image of Asni center in May 2022; (b) Satellite image of Asni center on September 2023; (c) Spatial distribution of transient housing in Asni; (d) Satellite image of Tlate Nyaakoub on May 2022; (e) Satellite image of Tlate Nyaakoub on September 2023; (f) Spatial distribution of transient housing in Tlate Nyaakoub. Source: Lansat images https://landsat.visibleearth.nasa.gov/ and authors.

Peripheral Village

In Tafghaght and Tizi ouadou, the seismic aftermath posed unique challenges, reflected in the scattered array of transient housing. Demographic surveys indicate that these households often host up to three or four generations, linking them intrinsically to their agricultural land. Here, the topography is unforgiving, yet the residents, whose mainstay is agriculture, have shown remarkable resilience. They have strategically placed their

temporary tents and structures to ensure proximity to their farmland (Fig. 6), maintaining the crucial link to their livelihood. Despite the rugged landscape, families endeavored to recreate the private courtyards integral to their daily life, setting up tents in configurations that aimed to replicate their pre-earthquake living conditions as closely as possible. This adaptation not only speaks to the physical needs but also to the cultural continuity, with each tent placement a testament to their enduring commitment to preserve their traditional way of life amidst the challenges of disaster recovery.

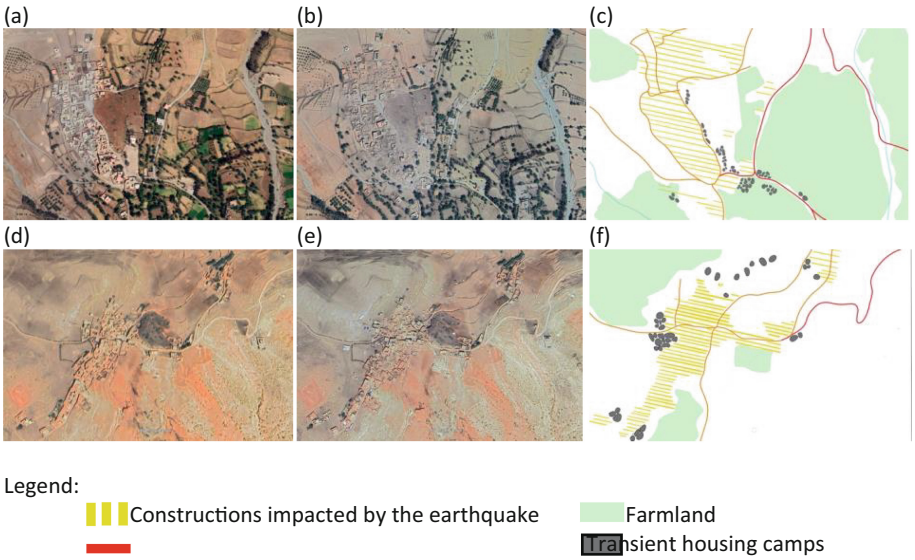

Fig. 6. (a) Satellite image of Tafghaght on May 2022; (b) Satellite image of Tafghaght on september 2023; (c) Spatial distribution of transient housing in Tafghaght; (d) Satellite image of Tizi Ouadou on May 2022; (e) Satellite image of Tizi Ouadou on september 2023; (f) Spatial distribution of transient housing in Tizi Ouadou. Source: Lansat images https://landsat.visibleearth.nasa.gov/ and authors

3.2 Adaptations Analysis

The extensive survey across the selected earthquake-impacted villages revealed that the average household comprised 5.4 members, with a strong preference for transient housing materials that offered thermal comfort and quick assembly, predominantly sourced from governmental initiatives and local supplies. The qualitative data underscored a resilient community fabric where, despite a scarcity of resources, there was an evident pattern of communal support and shared problem-solving. The demographic profile was diverse, with a balance in gender representation, occupations largely within the agricultural sector, and family structures spanning multiple generations. The adaptability of transient housing was found to be highly influenced by cultural context. Communities displayed spatial flexibility by repurposing or expanding shelters to accommodate family

units or communal activities, with modifications aligning with traditional practices like communal dining and social gatherings. Material durability was variable, with a general inclination toward enhancing resistance to environmental factors (Fig. 7). The construction and disassembly process was prioritized for its ease, reflecting the community's need for mobility and the potential for future relocation.

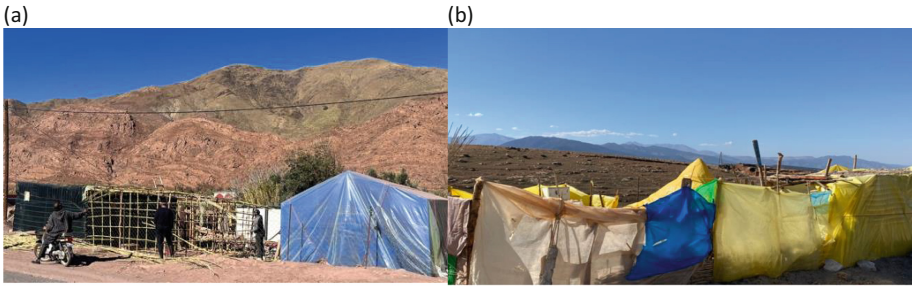

Fig. 7. Emergency houses community adaptation (a) Tafeghaght and (b) Tizi ouadou. Source: Authors on site pictures

Geolocation and spatial analysis revealed distinct patterns of housing organization. Central villages, such as Asni and Tlate Nyaakoub, exhibited structured clusters that optimized shared resources and reinforced community cohesion. In contrast, peripheral villages like Tafghaght and Tizi ouadou demonstrated a dispersed arrangement, indicative of individual space needs and a connection to agricultural livelihoods (Fig. 4b). Satellite imagery provided an overarching view of the damage extent and post-disaster landscape alterations (Fig. 6b and Fig. 6e). New communal areas emerged organically, signaling efforts to re-establish social structures disrupted by the earthquake.

The results from both survey data and field observations illustrate a community adept at navigating the complexities of post-disaster housing, displaying a resilient and adaptive approach tailored to their unique socio-cultural and environmental contexts.

4 Discussion

This research meticulously unravels the multifaceted transient housing strategies in the wake of a devastating earthquake in Morocco's Al Haouz region. Bridging local applications with global experiences, it provides a lens through which to examine the synthesis of urgent human needs with the resilience and adaptability of communities.

In examining the structured transient housing clusters within Asni and Tlate Nyaakoub, parallels can be drawn to the proactive disaster management approaches seen in rural Japan [13–15]. Japanese communities often implement pre-planned, organized clusters that enable efficient resource distribution and communal support [16–18], mirroring the structured approach seen in communes' centers. Peripheral villages displayed a more individualized approach to transient housing, with dispersed settlements that maintained agricultural practices and rural lifestyle continuity. This adaptation strategy is reminiscent of the post-disaster housing response in the rural areas of Nepal [19, 20],

where dispersed settlements allowed residents to remain close to their farmlands, thereby sustaining their livelihoods even in the aftermath of a disaster [21].

The diversity in housing strategies between communes' centers and peripheral villages reflects broader socio-economic and infrastructural dynamics. Centralized communities, better equipped with resources and infrastructure, naturally gravitate towards organized structures, enhancing automated, community-based housing response framework [22]. This can emphasize customized housing plans tailored to displaced populations, resonating with the centralized approach. Conversely, the peripheral villages, which face mobility and resource access challenges, maintain dispersed housing patterns to adapt with the site topography. This pattern is indicative of the need for adaptable temporary housing, as highlighted in Chile and Peru, where families adapt their houses to meet their midterm needs [23], emphasizing the importance of guidance in safely altering temporary structures.

Moreover, the insights from researches exploration of temporary housing in earthquake relief work, which emphasizes integral use of containers [24], offer an interesting contrast to the local material preferences observed in Moroccan villages. However, the Moroccan reliance on local materials for quick assembly echoes the sustainable approach advocated in the literature [25, 26]. However, the basic form and composition of these emergency houses needs to be upgraded and adequated to thermal comfort and arid climate [27]. Equally, review of temporary housing management models further supports our findings, advocating for adapted management and sustainability in housing solutions [28, 29]. Moroccan communities' efforts to adapt their living spaces, despite limited resources, align with the community resilience required for successful post-disaster housing management.

The Moroccan approach to earthquake recovery, when viewed alongside global practices, reveals a dynamic process of adaptation that interlinks cultural resilience with practical environmental strategies and social unity. This synergy demands a thoughtful recovery approach, deeply rooted in community collaboration and forward-looking planning [30–33]. Strategic planning here is not just about immediate rebuilding but about cultivating a culture of resilience, sustainable development, and the capacity to thrive post-adversity.

Resilience in this context is iterative, with each cycle drawing on new learnings and community strength. It's about leveraging local insights for a living, evolving strategy for reconstruction that transforms the remnants of disaster into the foundation of a stronger, more adaptable society [34, 35]. The aim is to embed resilience into every aspect of strategic planning, ensuring that every post-disaster decision contributes to a future where communities are not just protected from natural calamities but are flourishing alongside them. Morocco's experiences, echoed by global recovery efforts, chart a course toward resilient rebuilding and sustainable growth in the aftermath of earthquakes.

5 Conclusion

The study of post-earthquake transient housing in rural Morocco provides a compelling narrative of resilience and adaptability. The earthquake of September 2023 not only tested the structural integrity of housing but also the social fabric of the affected communities.

In the face of adversity, the varied responses—from the structured clusters in Asni and Tlate Nyaakoub to the dispersed individualized adaptations in Tafeghaght and Tizi ouadou—highlight a collective ingenuity rooted in deep-seated cultural practices and a profound connection to the land.

The comparison with international illustrates a universal challenge in post-disaster housing: balancing immediate needs with long-term sustainability and cultural integrity. This study has shown that while tents offer a quick-fix solution, they are a precursor to more nuanced, culturally sensitive, and socially cohesive housing strategies.

Our findings underscore the critical need for a strategic, context-specific emergency planning framework that accounts for both the socio-cultural nuances and the geotopographic realities of rural settings. Such a framework should not only facilitate rapid deployment of emergency shelters but also pave the way for sustainable, community-driven housing solutions. The insights garnered from the Moroccan experience contribute to a growing body of knowledge that underscores the importance of localized, participatory approaches to disaster recovery—approaches that honor the cultural, social, and economic fabric of communities.

The adaptive strategies of Morocco's rural communities in the aftermath of the 2023 earthquake reflect a broader narrative of human resilience and the capacity for innovation in crisis. These strategies, born out of necessity, have the potential to inform and enhance future transient housing interventions, ensuring that they are not only responsive but also respectful of the communities they aim to serve. This study calls for a continued dialogue on post-disaster housing, advocating for solutions that are as dynamic and diverse as the communities they support.

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The Landscape from Architecture to the City: Strategies and Methods to Regenerate Through Design

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Abstract. The contribution intends to propose an innovative and transdisciplinary approach to restore centrality to the landscape in the process of urban regeneration. The urban landscape, in its naturalistic-environmental dimension, is an essential part of cities: both as a physical object and from a perceptive, cultural, and social point of view. It is a continuously changing system also due to the different forms of anthropization, whose effects it sometimes suffers. The landscape system possesses a potential that has yet to be developed, especially in this phase of ecological transition affecting cities. The point of view needs to be reversed to understand what actions need to be taken to recover fragments of the (diffuse) landscape within cities, to promote activities and projects also in water edges and buffer zones by graduating the possibilities of use and protection. How many opportunities and opportunities does the landscape offer in its 'transversal' dimension? The essay will illustrate some virtuous examples of Italian and international case studies on the methodologies of knowledge, design, planning, restoration of the urban and rural landscape. This is the aim of our contribution: to propose new methods, at the various scales of the project (rural architecture, landscape restoration and dynamic management of its transformations, landscape as an element of architectural design, landscape planning) for the valorisation of the landscape by encouraging renaturalization and promoting forms of rewards for the sustainable use and protection of landscapes in their various articulations.

Keywords: Landscape regeneration · Rural and urban landscape · Landscape design · Waterfront landscape · Transdisciplinarity · Landscape restoration

1 Introduction

In Italy, the debate between conservation and transformation in the context of sustainability has long focused on preserving landscapes, cultural heritage, and historic centres through various protection regimes. While early efforts primarily aimed at conservation,

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subsequent regulations and directives have expanded to encompass the entire territory, including areas with potential for tourism and sustainable development. The shift towards prioritizing valorisation compatible with heritage protection has led to considerations of landscape feasibility for various projects, including renewable energy installations. However, recent developments have seen a radical change in approach, with exemptions from regulations and incentives for renewable energy production becoming more prevalent, reflecting a reversal in the traditional conservation paradigm.

The evolving landscape and urban environment present challenges in responding to the demands of the ecological transition. With most Italy's municipal territories comprising agricultural land [1, 2] and forests, the need to balance conservation with necessary transformation is becoming increasingly apparent. As cities and territorial contexts participate in the ecological transition, the concept of urban resilience takes on multiple meanings, emphasizing the capacity to adapt to new challenges while aligning with the recommendations of Agenda 2030. These dynamics underscore the imperative to move beyond static conservation concepts and embrace necessary transformation in or-der to effectively navigate the era of transitions.

This complex interplay between conservation, transformation, and the ecological transition underscores the need to reassess priorities and paradigms in urban and territorial planning. The multifaceted meanings of urban resilience and the evolving demands of the contemporary world highlight the imperative for adaptive responses and a forward-looking approach that aligns with the goals of sustainability and resilience.

Sicily boasts a diverse and captivating landscape, characterized by a rich tapestry of natural and cultural elements. The relationship between rural landscape and architecture in Sicily is intricate, encompassing both the natural and cultural dimensions. The rural landscape in areas like Enna seamlessly integrates with the urban context, blurring the boundaries between architecture and nature. The diverse forms of agriculture, such as vineyards and olive groves, contribute to the distinctive character of the landscape, offering development potential linked to tourism, agriculture, and crafts.

The agrarian landscape in Sicily is undergoing transformation and expansion, driven by processes of productive rationalization and cultural reconversions. The interplay between architecture, agriculture, and landscape in rural centres reflects a profound historical continuity and stratification of land use. These rural settlements exhibit a unique physical and formal structuring, with building typologies closely intertwined with production, product transformation, and conservation activities [2].

The process of urban reforestation is particularly relevant in Sicily, where agricultural green spaces [3] form a dense ecological infrastructure with far-reaching implications. The aesthetic filters of the rural landscape and reforestation processes significantly contribute to the overall quality of the landscape, exemplified in municipalities like Taormina, Leonforte, and Ortigia. These areas showcase the intricate relationship between human activities, historical heritage, and the natural environment, underscoring the importance of sustainable resource utilization and cultural valorisation.

Looking ahead, Sicily is well-positioned to align with the sustainable development goals outlined in Agenda 2030 [4] and the EU's 2026-time target for the National Recovery and Resilience Plan (PNRR). The region's rural tradition, rooted in the sustainable use of resources and the valorisation of cultural heritage and local traditions, provides a

strong foundation for implementing sustainable activities and restoring the centrality of the urban landscape while safeguarding ecosystem services. Sicily's cultural and environmental heritage, combined with its rural traditions, presents a promising opportunity to over-come obstacles and promote sustainable development in harmony with its natural and cultural landscapes.

The Sicilian landscape has undergone significant transformation due to technological innovations in agriculture, leading to the loss of its historical agricultural character. The neglect and decay of the architectural heritage [5] in the hinterland also pose challenges. Efforts to protect and promote the rural landscape as a cultural asset have been made, including initiatives by the European Union and local administrations. These efforts aim to mitigate the wear and tear caused by traditional tourism and provide new opportunities for neglected areas.

The Regional Center for Planning and Restoration (*Centro Regionale per la Progettazione e il Restauro* - CRPR) has started in 2006 the drafting of the Regional Map of Places of Identity and Memory (*Luoghi dell'Identià e della Memoria* - LIM). Additionally, the Leader II program focused on cataloguing heritage for tourism, and the Rural Development Programme aimed to improve rural life and diversify the rural economy. The Sicilian Region also initiated projects for the recovery and valorisation of rural villages [6].

However, there is a need for global operational coordination to recover this heritage and recognize its cultural value. An integrated design approach is essential to update the forms of protection and reintroduce these assets into contemporary life while preserving their authenticity and symbolic functions [6]. This approach should draw from the identity and roots of the landscape to regenerate the rural heritage for the future.

Landscape plays a crucial role in architectural design and urban planning, serving as a valuable resource that requires continuous care and attention. The quality of the landscape and open space is essential for ecological transition and sustainable development. Integrating nature into urban infrastructure, such as introducing green spaces and vegetation, can mitigate the impact of urban development on the environment.

With a significant portion of the global population residing in cities, it is imperative to focus on integrating the plant aspect into urban infrastructure to restore ecosystem services and create more sustainable and liveable spaces. Projects like '*SEMEUR*' in Lyon, which integrates green spaces with the tramway, exemplify this approach.

Coastal cities face unique challenges and opportunities due to their proximity to water. Urban and landscape rehabilitation projects in coastal cities must consider the presence of water as both an asset and a potential complication. Climate change further accentuates the complexity of coastal city design, requiring innovative solutions to address the impact of storms and erosion on coastal infrastructure [7].

In response to these challenges, some coastal municipalities have opted for the renaturalization of coastal areas, dismantling fixed structures and retreating inland to create more space for the beach and sea. This approach prioritizes sustainable and regenerative solutions, aiming to redesign public spaces with respect for town planning and the environment.

Additionally, initiatives such as the '*Plan de Acción del Paisaje*' in Santurtzi demonstrate a commitment to sustainable transformation and the consolidation of coastal areas.

By reimagining urban beaches and creating new leisure areas, these projects aim to bring cities closer to the sea while preserving the natural landscape.

Ultimately, the goal is to harness the continuous energy of waterfronts and coastal areas to achieve a perfect interaction between anthropization processes and the surrounding landscape. By embracing transversal and integrative design visions, cities can create more liveable and sustainable environments that harmoniously blend architecture and nature. This holistic approach, guided by the wisdom of nature, holds the key to addressing climate change and creating a healthier, more vibrant urban landscape [8].

2 Literature Review

The essay aims to highlight, through an extensive review of the literature - organized according to two in-depth focuses, landscape conservation/transformation in regeneration process and Architecture and urban reforestation in Sicily - how much the approach to the theme of conservation/transformation, in its ambiguous relationship, is also to be actualized with respect to the new demands of the territory and the solicitations of European programming in terms of responses to environmental challenges, the necessary involvement of the landscape (in all its forms and typifications) and green infrastructure, ecosystem services, and complex and sensitive areas such as coastal contexts.

2.1 Landscape Conservation/Transformation in Regeneration Process

For many decades, in Italy, the orientation of the debate between conservation and transformation in the light of sustainability objectives [1, 2], has been to preserve landscapes, cultural heritage and historic centres with the recognition of different protection regimes -from reconnaissance landscape restrictions, to the perimeter of homogeneous zone 'A' in the PRG, the "*Piano Regolatore Generale*", and with restrictions introduced on 'permitted and prohibited building activities' as a result of the two laws, no. 1089 and no. 1497 of 1937-, aimed substantially at conservation. For years the rest of the territory remained almost always without specific control restrictions, in the case of the inhibitory or tutelary type, except for prescriptions deriving from very sectorial regulations (think of the Royal Decree for water courses, for example). Around the 1970s/80s, with l. 431/85 and the sector regulations (l. 183/89, for example), the rest of the territory was also subjected to binding regimes. One thinks of the framework law on parks and protected areas and the EU (European Union) directives for the Natura 2000 Network. It was probably believed that a wide protection grid, with more or less narrow networks, could preserve the territories. In some cases, it has served to inhibit and avert the risk of damage and compromise to centres of historical and cultural value and landscape areas [2–4],

In other cases, the system of constraints, used without any effort at gradualness, has in fact prevented the use of areas with a vocation for tourism and sustainable enhancement. With the 2004 Code of Cultural Heritage, there is a reversal of this trend: constraint for its own sake is not the priority, but valorisation compatible with heritage protection is. Despite this, many landscape plans - I cite Calabria's QTRP (*Quadro Territoriale Regionale a valenza Paesaggistica)* as an example, but the reasoning extends to the

landscape plans of many regions - introduce the 'new landscape contexts' and emphasise the need to verify the compatibility of transformations. A few years after the issuing of the 2004 Code, for example, even for energy production plants from renewable sources (wind and solar, now considered necessary works for the environment and for the ecological transition) the verification of landscape feasibility was envisaged as part of the EIA with respect to the national Guidelines containing the explication of the criteria for the choice of sites suitable for the installation of plants.

Today, the situation has changed radically. The ecological transition can be implemented if incentives are given, also, for the production of energy from renewable sources, and exemptions from regulations are allowed, as the case may be. The paradigm has changed and there is definitely a reversal: the landscape and the environment participate in the ecological transition, sometimes giving up something. Today it is for the 5Giga, the *Piano Casa/Sisma Bonus,* the Superbonus110 and many derogations are allowed.

The term 'conservation' indicates the maintenance of an object in a state of efficiency so that it is in a condition to be used, protecting it and preserving it from alteration. It presupposes a pro-active approach that can guarantee the functioning and efficient state of the object thus protected.

The legal measure of the so-called 'protection regime' applies to defend, protect, preserve against possible damage, offence, or other unlawful actions.

Preservation of a cultural and environmental asset, be it the historical centre or the landscape, means any activity carried out with the aim of maintaining its integrity, identity, and functional efficiency in a coherent planned and coordinated manner.

Is conservation as a condition of absolute, binding protection of the asset to be protected nowadays, in the light of the widespread demand for transformation, impractical?

And yet, ignoring at times the "bringing of control instruments" we have arrived at the "ope legis" constraint to which the urban planning instruments refer to, as if they were administrative burdens. With the feeling that nothing can be done.

In reality, the city and the landscape are transforming entities. The various anthropic interventions of different periods have shaped today's *forma urbis*, which is the result of historical stratifications. Landscape is also not a static category, it is the "result of modifications of the environment brought about by land use" (European Council) whose appearance results from the action of human and natural factors and their interrelationships. Classical' urban conservation policies, by concentrating hypertrophically on a few historical parts, have neglected the heritage value of important areas of the modern city or rural town. Most of Italy's municipal territories (Fig. 1) are made up of agricultural land and forests (at least 70%), the rest by urban settlements (24%, containing a small amount of urban green spaces), water bodies (5%) and less than 1% by uncultivated land, marshes, and sandy soils [3, 5, 6].

Today there are many challenges. The acceleration of processes of change and the discontinuity of synchronies between space and time characterise the contemporary world we live in and experience. Cities are not prepared to provide adequate responses to the great social and economic changes and challenges of the era of transitions [4, 5].

Everything takes place within the urbanised city, be it the historic city or the consolidated city, and the territorial context participates with it in the ecological transition to

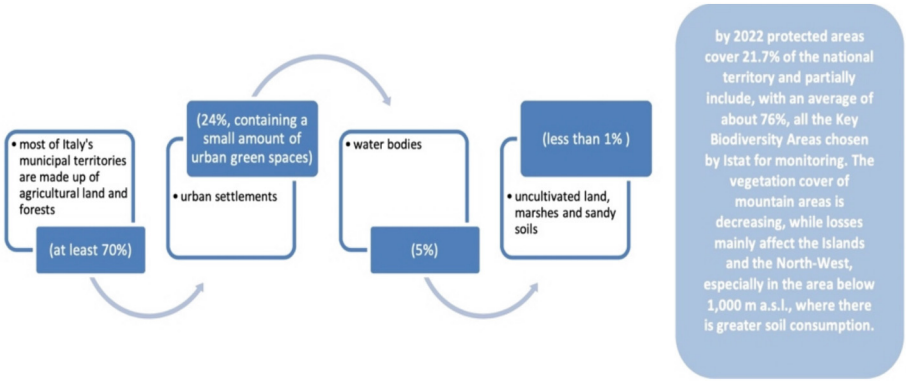

Fig. 1. Land cover at municipal level and in percentage of area. Source: elaboration by Celestina Fazia.

which it is called to respond. To accomplish the ecological transition, some paradigms and orders of priorities may have to be revised.

The meanings of the concept of urban resilience, at the basis of the PNRR which indicates the ecological transition as a necessary condition, are multiple. In general, the term takes on the meaning of resistance, as the capacity of the urban organism to respond to external stresses by absorbing them and restoring its functions in the shortest possible time, but it also means being ready for the future, modifying oneself by adapting one's resources to meet the new challenges that arise, sometimes without 'remorse'. Moving beyond the static concept of conservation, towards that of necessary transformation, also goes in this direction in light of the numerous recommendations contained in the 17 goals of Agenda 2030 [4, 5, 7, 8].

2.2 Architecture and Urban Reforestation in Sicily

Sicily is a palimpsest of landscapes of extraordinary beauty. The morphological variety is remarkable: from hills crossed by streams, to terraced plateaus, to inland slopes and coastal landscapes or centres. Based on this initial classification, the relationship between rural landscape and architecture can be described through the fundamental elements, namely the natural/vegetational dimension and the cultural/perceptual dimension. The complexity can be grasped either by using the critical approach of Creuze de Lesser or the spirit of Norman Douglas, with attention to those fragments where the landscape becomes a place of contamination of history and forms of production.

The relationship between architecture and urban reforestation originates from the structure of the landscape, the components that define urban or rural identity and the characteristics they take on through the modes and types of production. These components are associated with those identifiable in the vegetation system and the human actions that transform the landscape, typical of certain territorial contexts, such as that of Enna. The rural landscape in Enna insinuates itself into the urban context, where the absence of physical limits does not 'contain' the push towards urban reforestation (lower Enna). Architecture and rural landscape merge.

The different forms of agriculture present in the rural territory express as many forms of landscape: vineyards and olive groves, for example, are among the characterising elements. The Enna hills depend on the economy of the valley floor and have development potential linked to the protection of the landscape, the combination of tourism-agriculture or crafts-agriculture. They are often typologies with ecological value, identifiable as areas of diffuse naturalness that are often intertwined with human activities that constitute limiting factors. They are areas of interchange of extraordinary importance and subject to continuous evolution.

The agrarian landscape is undergoing transformation and expansion, on the one hand due to agrarian processes of productive rationalisation, and on the other hand due to cultural reconversions. In many rural centres in Sicily, architecture, agriculture, and landscape are difficult to separate: their relationship is characterised by an extraordinary continuity and a specific historical stratification of uses and forms. Rural settlements have rules of physical-formal structuring, while building typology is the result of functional relations with the places deputed to production, product transformation and conservation [5, 6]. It is not difficult, in these centres, to think of a process of urban reforestation as the (agricultural) green represents a continuum, an ecological and environmental infrastructure with dense ramifications. One thinks of the rural centres of Zafferana Etnea, Acitrezza, Leonforte or Ortigia [6, 7]. Relationships with the extra-urban landscape depend on the presence of environmental emergencies, particular altimetric and geographical conditions, and more or less intimate proximity to water and nature. Zafferana Etnea is among the municipalities included in the Etna Park. In the neighbouring territory there are no inhabited centres, and the diffuse city is located at lower altitudes near the towns of Nicolosi and Pedara [7, 8]. The historical and cultural heritage consists of the isolated assets that mark the territory, high mountain refuges and architecture serving agriculture. The economy of the Acitrezza area has been transformed over time because of different historical contingencies. The historic centre, which today is a complex of rural architecture, two centuries ago represented the town's gateway to the farming world.

The components of the rural landscape and reforestation processes present in some centres are the aesthetic filters of the territory and play a decisive role in the quality of the landscape, as in Taormina. In Leonforte, a municipality in the province of Enna, the inhabited centre is located in the Erei mountain system [8] and presents the characteristic features of historic towns and the widespread presence of demo-anthropological elements, forms of agricultural production and processing, such as rational systems for crop irrigation and numerous water mills. Of considerable ethno-anthropological interest are the finds of industrial archaeology including the Faccialavata Sulphur Mine, the Spinning Mill and the artefacts still present along the old Dittaino-Nicosia railway line.

Ortigia is an island located on the east coast of Sicily, a strip of land joins it to Syracuse. Due to its geological conformation, it lends itself to the natural seepage of water, so much so that the island is connected to the mainland of the city of Syracuse and through the water the processes of interchange between green and blue infrastructure take place. Reforestation in these contexts is an easy process to implement; there is no need to intervene artificially to boost the natural re-appropriation of areas that are already suited to being subservient to nature and its rules.

In line with the 17 Goals of Agenda 2030 [5, 6, 8], and within the 2026-time target set by the EU for the PNRR, it will be possible to complete numerous sustainable activities and actions [9] to restore the centrality of the urban landscape and the restoration of ecosystem services subtracted and swallowed up by urban logics detached from the protection of environmental balances. In Sicily, this process will encounter fewer obstacles because there is a (widespread, even if in some areas it is not prevalent) rural tradition that encourages a sustainable use of resources through the valorisation of cultural heritage, material culture and local traditions [10].

3 Discussion

The case studies analyzed point to the need to address some priority issues: urban reforestation and rural landscape conservation and the Regeneration and coastal urban landscapes, methods, and results from international cases also in progress. The issues of reforestation and coastal areas provide an opportunity to initiate discussion and provide answers also through the interpretation of the results of best practices and successful experiments.

3.1 Rural Built Heritage and Landscape Conservation

In the present day, Sicily preserves only a fragment of its extensive rural heritage, owing to the legacy of plants, animals, agrarian practices, land utilization and social relationships that have been left over from many cultural civilizations, contaminations, and stratifications. In the latter half of the 20th century, the landscape has undergone significant changes due to the implementation of revolutionary national land policies. In 1950, following the establishment of Sicily as one of the four autonomous regions of Italy, an agrarian reform was implemented. By setting up the Agency for Agrarian Reform (*Ente per la Riforma Agraria in Sicilia* – ERAS) together with the financial resources provided by the Fund for the South (*Cassa per il Mezzogiorno*), an agency created by the Italian Government, the program incited agriculture to its greater intensity since the apex of Norman era. However, projects were formulated without a proper understanding of the physical and human geography of Sicily, leading to their failure [11, 12]. Even though productivity increased dramatically, the island's countryside was transformed from 'agricultural' to 'rural' due to a profound and definitive territorial reorganization [13]. Technological innovation in agriculture very often used indiscriminately and without proper assessment, the abandonment of polyculture towards monoculture, the agriculture mechanization and the unsafe usage of pesticides and herbicides for the weed control, generated a profound alteration of its layout.

In recent years, the rural landscape, largely marked by phenomena of degradation and abandonment, has become an emerging issue at international, national, and regional levels, in the now widespread awareness that its safeguarding and valorisation would play an essential role in sustainable socio-economic and cultural development. In this regard, the European Union has promoted numerous initiatives to transform these areas in sustainable development laboratories by enhancing their cultural and natural heritage. However, these programs are still struggling to show truly perceptible results, perhaps

due to the complexity of the phenomena involved and/or because they are not yet sufficiently based on a perfect awareness of the culture of places, seen as space-time entities, repositories of testimonies and relationships from which every subsequent action should derive. A knowledge based on the understanding of the marks still existing in the territory and of the links with their interpreters, in the mindfulness that, as stated by the Charter of Krakow - principles for conservation and restoration of built heritage (2000): "Each community, by means of its collective memory and consciousness of its past, is responsible for the identification as well as the management of its heritage" [14].

The Sicilian rural buildings, which bear the memories of past life, ancient construction techniques, craftsmanship and lifestyles and contain the spirit of cultural landscape, are an essential component of this system and require a holistic approach for their protection. Globally, they are experiencing problems of neglect, decay, and poor accessibility due to rural depopulation, which caused the deprivation of their original function. In other cases, they are at risk of mischaracterization due to refurbishment activities that prioritize modern architectural trends and industrial materials over traditional ones, leading to a progressive loss of traditional knowledge and skills [15, 16]. Nevertheless, these elements demonstrate the existence of local construction logics that allow them to be traced back to the building typologies they belong to. Despite their growing depredation due to meteorological, climatic, and environmental factors, certain constructions and settlements have managed to retain their authenticity and integrity to a certain extent and are now waiting for new functions. If subjected to appropriate revitalization actions, it could prove to be strategic, especially for inner Sicily: an area with great patrimonial wealth, but historically less frequented and still lacking sufficient attractiveness for tourist flows due to the lack of coordinated and strong policies in the sector.

Supporting framework of an organizational system related to agricultural life and distinctive elements, in form and material, of the identifying characteristics of the cultural landscape, these assets deserve to benefit from specific, detailed, and accurate knowledge activities to be reintroduced into the life cycle in a conscious and conscientious manner. The methods implemented for their protection have so far favoured the monumental heritage and the historic urban centres, even if, historical rural buildings are perceived as cultural assets to be preserved according to the Convention for the Protection of the Architectural Heritage of Europe (Granada, 1985) and the European Landscape Convention (Florence, 2000). Since 1992, UNESCO considers rural landscapes as biocultural mosaics and has designated them as the most common types of 'continuing cultural landscapes', a category of World Heritage.

The same architectural and urban planning culture in Italy, in recent years, has been predominantly characterized by a tradition of an urban-centric nature, seen as the conceptual prerequisite and the goal of a vision that subordinates the suburbs, the open territory, the countryside to the city. Only recently, the fate of rural architecture and villages has overcome conditions of secondary importance to take on a strategic role in the rebalancing and development of the territory, but also a scientific and cultural interest, rich in possible innovative values [17]. Following the ICOMOS-IFLA ISCCL Milano Declaration on Rural Landscapes (2014), the Principles Concerning Rural Landscapes as Heritage were approved by the IFLA in October 2017 and adopted as a doctrinal text

by the ICOMOS General Assembly in Delhi in December 2017. The document encourages thorough reflection and provides guidance on the ethics, culture, environment, and sustainable transformation of rural landscape systems, at all levels, both internationally and locally. It provides principles and criteria for the protection and promotion of heritage related to rural landscapes, focusing on the steps to be taken. Its goal is to promote an appropriate balance between economic, social, cultural, and environmental aspects [18].

After the experience of the COVID-19 pandemic, the European Commission has allocated significant resources in the Next Generation EU Programme to promote rural development strategies as a response to the global health crisis. Rural areas are no longer identified as areas outside urban centres, but "places with important environmental, natural and cultural assets, where local actors play a strategic role in the preservation of biodiversity and soil, as well as cultural heritage" [19]. The recovery of rural architecture can offer several benefits, playing an essential role in sustainable development and cultural safeguarding. Contemporary architecture and urban planning can be improved by incorporating the intrinsic values of traditional rural built to create culturally rich and socially connected communities. However, locals and other stakeholders need to have a complete understanding and appreciation of the intrinsic values of this heritage for this process to be successful.

In Sicily, regional and local administration have understood that the rural landscape is a resource to be protected and promoted, together with other sectors connected to it such as culture, food, tourism, ecology, health, and well-being. The Regional Center for Planning and Restoration (*Centro Regionale per la Progettazione e il Restauro* - CRPR) has started in 2006 the drafting of the Regional Map of Places of Identity and Memory (*Luoghi dell'Identià e della Memoria* - LIM). The aim is to expand the protection and enhancement of the cultural and environmental heritage of Sicily to include the places and buildings that contribute to the island's identity and cultural memory. In Sicily, the traditional model of tourism focuses on a few monuments and monumental complexes in urban contexts or on archaeological parks and sites, or even on the tourist resorts located along the coasts and in the tiny islands which surround it. This results in a significant anthropic pressure that the charter aims to alleviate. Applied across the entire territory, it also intends to provide new opportunities to territorial areas neglected by the main visitor flows, by proposing often unexplored itineraries, through places and routes that characterize the rich complexity of the Sicilian cultural landscapes.

The Leader program introduced as a 'Community initiative' and financed under the EU Structural Funds across rural Europe stipulated that artistic, archaeological, and naturalistic heritage be inventoried so that it could be accessible to the tourism industry. This research, implemented in Sicily by the Sicilian Region, has focused on finding themed itineraries, including the rural naturalistic route known as 'The Ways of the Water Mills'. Improving the quality of life in rural areas and diversifying the rural economy has been the goal of Axis III of the Rural Development Programme. Sicily 2007/2013, which has made significant funding available for the conservation and upgrading of the rural heritage: sites of high naturalistic and landscape value (ponds, crossroads, hedges, indigenous monumental tree specimens) and cultural elements of the traditional agricultural landscape (isolated buildings of rural historical-architectural

interest to be used for public use, artefacts such as dry-stone walls, terraces, troughs, etc. Within the same programme, in 2009 the Sicilian Region drew up a pilot project for the recovery and valorisation of the rural villages of the Agricultural Development Board (*Ente Sviluppo Agricolo* - ESA) established in 1965 to replace ERAS called '*La via dei borghi'* which saw its first concrete manifestation in the intervention of redevelopment of Borgo Bruca, starting point of the itinerary, located in the municipality of Buseto Palazzolo, in the province of Trapani. Two other rural villages - Libertinia, which falls in the territory of Ramacca, and Pietro Lupo, which is part of the Municipality of Mineo - became part of the project in 2019 while restoration activities are not started yet due to operational difficulties [20]. In 2022, the Italian National Recovery and Resilience Plan (PNRR) provided Sicily with over 76 million euros to restore and enhance its rural architectural and landscape heritage. 565 projects were admitted for financing aimed at enhancing and making more modern and functional a built heritage, which includes farms, farmhouses, stables, mills, or even small rural churches that will thus be able to return to being living garrisons of the territory, also with cultural and touristic purposes.

These initiatives, while not exhaustive, show a process already underway that considers the rural landscape as a cultural expression of memory, collective identities, and recognisability: the "shape that man, in the course and for the purposes of his agricultural productive activities, consciously and systematically imprints on the natural landscape" [21]. Despite these actions, there is still a lack of global operational coordination focused on recovering this heritage, based on its recognition through the analysis of artefacts and sites in the context in which they are located.

Operational research tools, such as inventory and cataloguing aimed at the characterization of the built heritage can be used in a shared methodology that provides comprehensive information and documentation, making it a valuable resource with a wide range of potential uses. The data gathered from the inventories - implemented by the research and analytical review of historical documents, a direct, extensive, and detailed reading of these assets, and efficient three-dimensional survey techniques - supported by Information and Communication Technologies (ICT) have huge potential for preservation and didactic-educational purposes. By engaging and activating them, they can increase people's interest in the uniqueness of culturally significant properties. The insights they give can serve as a basis for planning ongoing investigations, as they can efficiently provide valuable information [22]. An essential starting point for any subsequent evaluation and critical representation of the built space as well as for the establishment of design proposals coherent with both the valorisation of the permanencies and the adaptation of the values susceptible to change for the purpose to make them suitable for today's needs, in harmony with the environment and the values embodied in the territory.

It is indeed essential to launch new integrated design paths in which to bring together the theoretical-methodological and technical-operational contributions of architectural and urban conservation, adaptive reuse, structural and energy retrofitting, and coherent responses to the imperatives dictated by economic sustainability to make this heritage suitable for satisfying civil, cultural, and environmental needs. Hypothesizing harmonious and sustainable functions will be necessary for producing the necessary regenerative sap from the landscape itself.

3.2 Regeneration and Coastal Urban Landscapes, Methods and Results from International Cases in Progress

Landscape, its understanding, protection and valorisation has enormous potential in the interpretation of any context, and is undeniably of extraordinary importance as a fundamental element and tool for correct architectural design and urban planning.

The landscape system is a unique resource, only partially "renewable" and under certain conditions; it is a collective heritage in continuous change that requires continuous care and attention both in architectural and urban planning terms and in ecological, economic and social terms.

The quality of the landscape and open space is also a pivotal element in strategies of ecological transition towards sustainable development models, models that are considered to require an approach to design with architectural, urban planning and landscape visions that are also quite transversal and integrative, perhaps with different, sometimes even opposing views, but always reconnected. Particularly when the ecological transition affects cities, it is necessary to identify all possible actions to be taken to make 'fragments' and pieces of landscape, even diffuse ones, resurface, recover and enhance them through design, within the cities themselves. There is no doubt that, when possible, nature in its various 'forms' offers the best way to transform our cities, helping us to stop thinking of them as places that only consume resources and emit pollutants, and start imagining them as regenerative, healthier and more liveable spaces, capable of offering benefits to the environment and society.

But it is also true that, although the presence of a green and/or blue spot is desirable in contexts that are often too compressed and built-up within cities, urban and landscape regeneration does not necessarily need the identification of large spaces to take place. How, then, can we bring nature and its benefits back to the big cities by reclaiming their passage? Starting precisely from the margins that fragment it, which sometimes seem to be the greatest element of rupture, and therefore from the individual infrastructures that cross it, including water edges, when present, often too much or completely denied. Just as when redesigning an object one starts from the edges, in the same way when talking about blue or green regeneration it would sometimes be enough to start from the edges, from the limits (sometimes almost only apparent), to redesign a new face of the city, restoring its urban ecosystems. Countless, in fact, are the possibilities offered by buffer zones and edges, if seen not as barriers but as obstacles to be overcome, each of which can sometimes become an important pretext and occasion for the development of valuable new opportunities.

It becomes important, for example, to be able to use the construction of new infrastructure to integrate the plant aspect. To mitigate the impact of urban infrastructures on the environment, it is basically enough to introduce into the project, in its immediate surroundings, the various benefits that nature offers us and that we enjoy, such as, for example, the shade of trees or water sources that allow us to have a more temperate climate or the purer air that comes from having more green spaces. Apparently, this is not just a designer's fantasy, but apparently the economist Carmen Cantuarias, a member of the Scientific Council of the *ITTECOP - Infrastructures de Transports Terrestres, Écosystèmes et Paysages* - research programme, led by the French Ministry of Ecological Transition, is absolutely convinced of this [23].

56% of the world's population lives in cities, or 4.4 billion, a figure that is set to double by 2050, according to the World Bank. The environmental economist, who is Peruvian but works in Paris, argues that, given this scenario, many challenges in terms of infrastructure and sustainability need to be addressed by placing the plant aspect at the centre of them. 'We need to see how infrastructure that provides a public service can also be a source of restoring ecosystem services, how this infrastructure that fragments our landscape can be an opportunity to restore urban ecosystems. This is precisely what, thanks in part to the economist, is being done in France with a project in Lyon, called *SEMEUR* (sower), which is part of the *ITTECOP* programme, in which the tramway not only brings better mobility between the centre and the suburbs, but also more green spaces. In fact, *SEMEUR* focuses precisely on the ability of infrastructure to accommodate and maintain urban ecosystem services through ecological soil restoration. "We know that the tramway's vegetation will not save us from heat islands, but it will encourage neighbouring buildings, shops and houses to integrate green spaces", explains Carmen Cantuarias, confident that the many works to be carried out in cities in Latin America or the rest of the world will also include this new paradigm [24, 25]. A tramway line under construction in the Lyon metropolitan area also aims to integrate the city of Saint-Fons to create a city based on the concept of proximity, so as to reduce car journeys within the city, favouring those by bicycle or on foot: thus recreating the more sustainable 15-min city, conceived by Carlos Moreno in 2016, which received renewed interest after the Covid-19 pandemic [26, 27].

This same approach, always guided by the search for sustainable and regenerative solutions for the landscape, naturally to be calibrated on a case-by-case basis, cannot fail, but rather is perhaps even more exalted when we focus on other linear margins, on the water edges or sea fronts of coastal cities. They require a particular approach precisely because of the presence of the element water or sea. This, on the one hand, can be an obvious asset and facilitate sustainability in urban and landscape rehabilitation and regeneration projects but, on the other hand, it can sometimes prove to be a complication that, if poorly managed, can result in some green and sustainable solutions proving unusable or aberrant. It is necessary to study different water cities to go to their inner nature and thus whether they are open or closed to the sea, whether they are river cities, lake cities, but also whether they are tourist cities, seaside cities or predominantly port cities. This context makes evident the contemporary design complexity of coastal cities, whose urban spaces on the margins are in any case, though often denied, almost always the most identifiable spaces and therefore those from which to start again for a new operation of urban landscape regeneration of the same. And if until a few years ago this process identified at most a seafront promenade along the coastal edge, now we increasingly speak of an urban beach.

This is an ongoing process, but one that is also accentuated by climate change, so much so that even in some Spanish municipalities the decision is being made to demolish part of the *Paseo Marítimo* to make way for the urban beach (Fig. 2). Even the exceptional force of storm Gloria, which brought Spain to its knees in January 2020, has sharply highlighted how urban and landscape planning and design can no longer continue to turn its back on the nature of places. There was a realisation of the need to solve the problem

of beaches, promenades and breakwaters damaged by each storm with the aim of not repeating the same mistakes each time [28].

The first example of this transformation is taking place on the promenade of La Pineda in the municipality of Vila-seca (Tarragonès), one of the most emblematic and popular beaches on the Costa Daurada, but the municipalities of Calafell and Roda de Berà (Baix Penedès) and l'Ampolla (Baix Ebre) have also decided to stop investing in repairing their promenades given the continuous and intense winter storms that destroy them every year. A pioneering change of strategy in several municipalities of the Costa Daurada and the Ebro delta, which are continually punished by increasingly intense and frequent storms as a result of the weather emergency [29].



Fig. 2. The demolition of part of the *Paseo Marítimo* and the deconstruction works affecting part of the Plaça del Mil-lenari, built on the sand in 2002, Calafell, Spain, 10-01-2024. Source: La Vanguardia.

And so rather than the annual repair of the extensive damage caused by the waves to the promenades, they opted for the dismantling of the fixed concrete and asphalt structures, the renaturalisation of part of the coastal façade urbanised decades ago, and the retreat inland to give more space to the beach and the sea. The Ministry of Ecological Transition, on which the coastal zones depend, supports and defends these alternatives as the most sustainable and other municipalities on the Catalan coast are likely to follow the same path. Beach and seashore promenades are among the most attractive spaces in many coastal municipalities and deciding to reduce or end them is not easy, but if they prove to be impactful and obsolete, alternatives must be found, as the above-mentioned municipalities are doing. The important thing is to always redesign new public spaces with the utmost respect for town planning and the environment, readjusting them to be more attractive to both tourists and residents all year round. It is then the ability to be able to turn a problem into a solution and thus an opportunity for improvement that will determine success and new opportunities for the coastal cities in question [30].

In other cases, it is enough to go back to the origins of the cities themselves to initiate new projects of architectural and landscape regeneration by the sea. In this vein,

just a few months ago in Santurtzi, near Bilbao, in the Basque Country, the municipal council gave the green light to the new *Plan de Acción del Paisaje*, Action Plan for the Landscape, a document through which the seaside town will attempt to consolidate its process of moving closer to the sea. Santurtzi is thus starting the procedures to have an urban beach thanks to an agreement signed by the Santurtzi municipality with the Basque Government's Department of Tourism, Commerce and Consumption, which provides for the municipality to receive a subsidy of 2.2 million euros for the recovery and sustainable transformation of the coastline around the municipality's fishing port. This approach to the blue coat is also expected to be realised through the total dismantling of the tracks from the beach, with the creation of new leisure areas in the seaside town. "We have been working on this action plan for a long time, a document that will allow us to continue advancing in the most transformative and exciting project we have before us as a municipality: bringing Santurtzi closer to the sea", explained Aintzane Urkijo, Mayor of Santurtzi. The *Plan de Acción del Paisaje* is a very extensive document that divides the municipality into two areas: the urban area (with five prominent areas such as the Lehendakari Agirre seafront, the fishing harbour, the backside of Itsasalde Street, La Sardinera Park, and the vegetated cliff slope) and the port-industrial area that focuses on the Port of Bilbao facilities. "The aim is to redesign the existing promenade of Lehendakari Agirre to give it a greater variety of uses. In particular, a combination of green areas, a solarium and the revitalisation of the promenade through stairs, ramps and balconies is planned. Our goal is to return to the water", said Urkijo [31].

Returning to water is the fate of coastal cities, the reason for their birth and their inevitable destiny. It is impossible to think of intervening with the project without thinking of having to identify and perceive this continuous tension, a constant and inexhaustible energy that, if not captured, runs the risk of dispersing and even the identity of the places themselves. Waterfronts have always had a decisive impact on the birth, structure, economy and very image of their respective cities. These are the spaces from which to start with the project to consolidate the social, economic and environmental benefits as well, achieving a perfect interaction between the different anthropization processes in the area and thus wisely imprinting on the surrounding landscape, all of course thanks to the transversal and integrative design visions mentioned above. It is sometimes forgotten not only that "the Architecture_Nature relationship has its seal in the notion of landscape intended to regenerate the aesthetics of architecture" [32], but also that nature is capable of providing us with both the raw material and the instruction manual to regenerate living organisms such as the city and its landscape: it is the most effective tool to address climate change and the need for a healthier life, and thus to achieve more liveable cities from a holistic perspective that includes the various design aspects in perfect synergy with the social, economic and environmental ones.

Listening to the sea, therefore, to walk in coastal cities towards a greener and more sustainable future, and in this way, thanks also to a skilful and conscious complex and unitary design at all scales, regaining possession of the landscape. César Portela, recently awarded Spain's *Medalla de Oro de la Arquitectura* 2023 and recognised as a master of seaside design [33]. Not surprisingly wrote as much a few years ago about his seaside project in Finisterra, "I wanted first and foremost to respond to an order", to design "a

sublime place and in which architecture was able to join nature in a positive way, the same way earth, sea and sky have always done in that same place since all times" [34].

4 Conclusions

This first part of this paper investigates the approach to conservation and transformation in Italy that has shifted towards a focus on sustainable enhancement and compatibility with heritage protection, rather than absolute and binding protection. The importance of considering the dynamic nature of cities and landscapes, as well as the need to revise paradigms and priorities to achieve the ecological transition are also highlighted. Additionally, the interconnectedness of architecture, agriculture, and landscape in rural areas, and the potential for urban reforestation to contribute to the restoration of ecosystem services and the protection of environmental balances are emphasized.

The transformation and loss of the historical agricultural landscape in Sicily due to industrial policies, technological innovation in agriculture, and the abandonment of traditional practices are also highlighted. This work emphasizes the need for coordinated efforts to protect and revitalize rural cultural heritage and landscapes, which can contribute to economic, social, and cultural improvement. The initiatives promoted by the European Union [23, 25, 35] and regional policies demonstrate recognition of the importance of the rural landscape, but there is a lack of global operational coordination. The text also emphasizes the potential of landscape in architectural design and urban planning, as well as its role in ecological transition and the regeneration of cities. It suggests that even small spaces and edges can be opportunities for urban ecosystem restoration and the integration of nature into cities.

The main point of the third part is that integrating the plant aspect into urban infrastructure projects can help mitigate the environmental impact of cities and contribute to sustainability. This approach is being implemented in projects such as the Lyon tram-way and the transformation of coastal cities to adapt to climate change and protect against storm damage.

In conclusion, the text emphasizes the importance of reimagining coastal urban spaces to be more sustainable and environmentally friendly. By dismantling concrete structures, renaturalizing coastal areas [3–5], and focusing on regenerating landscapes, coastal cities can create more attractive and resilient environments for both residents and tourists. This shift towards a greener and more integrated design approach is crucial for addressing climate change and creating healthier, more liveable cities in the future [35].

Contribution Authors. Corresponding authors: although the research is the result of the work carried out jointly by all the authors, which Clara Stella Vicari Aversa is the supervisor, the drafting of the essay is to be attributed differently to each of them:

§ Abstract, by Celestina Fazia and Clara Stella Vicari Aversa; § 1. Introduction, § 4. Conclusion, by Alessandro Barracco; § 2. Literature Review and § 2.1. Landscape conservation/transformation in regeneration process, by Celestina Fazia; § 2.2. Architecture and urban reforestation in Sicily, by Maurizio Oddo; § 3 Discussion and § 3.1. Rural built heritage and landscape conservation, by Antonella Versaci; § 3.2. Regeneration and coastal urban landscapes, methods and results from international cases in progress, by Clara Stella Vicari Aversa. Graphics optimization and essay review by Clara Stella Vicari Aversa. Review by Celestina Fazia and Clara

Stella Vicari Aversa. It should be noted that paragraphs 1–2–2.1–2.2–3–3.2–4 represent the first results of research carried out by the authors both in their respective laboratories and in a joint convention between the two Universities entitled “A.Ma.Te Sponde”.

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Enhancing Urban Resilience Strategic Planning with MetaSWOT in Tehran's Historic Residential Districts

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Abstract. In recent decades, the escalating impact of natural disasters and climate change challenges has not only increased financial losses and casualties but also posed significant challenges to urban infrastructures particularly in historical areas. In the city of Tehran, which has a historical fabric and enduring social connections, preserving cultural and historical identity along with increasing resilience against crises is important. This paper aims to enhance physical and social resilience in residential neighborhoods within Tehran's historical fabric by introducing effective strategies to address future challenges. This article uses a quantitative and qualitative combined approach and is implemented in three key stages. The initial phase utilizes the Delphi method to identify and verify indicators of physical and social resilience. The data and opinions are gathered from experts who have knowledge and experience in the conditions of historical fabrics, resiliency, and the Meta SWOT method. Then, utilizing the Meta SWOT technique as a multi-stage analytical method, a strategic roadmap is formulated to enhance resilience in residential areas within the historical fabric. Finally, analysis and evaluation of the strategic roadmap were conducted based on predefined criteria to ensure that the proposed solutions effectively enhance neighborhood resilience. This article highlights the role of citizen education as an external factor in increasing their knowledge and participation in resilience processes. Additionally, it emphasizes the reinforcement of a sense of place and identity as internal and indispensable resources for sustaining and advancing social and physical resilience in historical fabrics.

Keywords: Resilience · Residential Neighborhoods · Meta SWOT · Strategic Planning · Historical Fabric · Tehran City

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1 Introduction

Iran is a disaster-prone country that has experienced more than 250 natural disasters over the past century, including floods, earthquakes, droughts, storms, and others [1]. Disaster is defined as hazards that cause widespread financial, human, economic, and environmental damage, as well as the inability (or exceeding the ability) to deal with these factors due to the lack of resources in the community or society [2]. They damage ecological systems, reduce economic outputs, and cause death and disease, which are extremely costly for the well-being of society and individuals [3]. To further the sustainable agenda and protect development gains, it is essential to shield socio-economic assets and the environment from rising risks, signifying the need for achieving resilience in cities [4]. Resilience is a versatile concept used in engineering, ecology, social sciences, and psychology [5]. Resilience has gained significance as one of the primary goals of empowerment in recovery and reconstruction after crises. Today, for some researchers with a positivist perspective, resilience is defined as the ability to return to a stable state after any disruption in the system's performance or as the capacity to absorb forces or changes with the least disruption to its functionality [6].

In the contemporary urban landscape, the concept of resilience has emerged as a critical framework for strategic planning, particularly in the face of environmental, economic, and socio-political challenges. Tehran's historic residential districts, rich in cultural heritage and socio-economic significance, stand at the crossroads of vulnerability and preservation. The introduction of MetaSWOT—an innovative analytical approach combining the traditional Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis with a meta-analytical layer—offers a nuanced pathway to enhancing urban resilience. This article delves into the application of MetaSWOT in Tehran's historic residential districts, aiming to provide a comprehensive strategy that not only safeguards these areas against various risks but also leverages their unique assets for sustainable urban development. Through a meticulous examination of the specific challenges and opportunities inherent in these districts, the study unveils a tailored, actionable plan that aligns with global sustainability goals while honoring the historical and cultural essence of Tehran.

2 Methodology

In this research, an initial Delphi method was employed to meticulously explore the indicators of physical and social resilience in the historical fabric of Tehran. Subsequently, utilizing the MetaSWOT technique, a strategic plan for residential neighborhoods within the historical context of Tehran was presented.

The Delphi method, developed in the early 1950s, is a structured communication technique for gathering expert insights on a specific subject, typically through questionnaires [7]. MetaSWOT, an advanced iteration of traditional SWOT analysis, was introduced in 2012 by Agarwal and his team at Tuiret College, USA, focusing on leveraging a group's strengths and resources to impact future outcomes [8]. MetaSWOT serves as a strategic planning tool, reflecting the current trend where companies, organizations, and institutions are confronted with both external-to-internal and internal-to-external

strategic planning approaches [9]. In summary, this technique comprises seven stages: Stage 1 – Identifying research goals and prioritization, Stage 2 – Identifying and rating resources and capabilities, Stage 3 – Identifying competitive dimensions, Stage 4 – Evaluating resources and capabilities based on VIRO criteria, evaluates the four elements of Value (V), Rarity (R), Imitability and Non-substitutability (I), and Organization of internal resources and capabilities (O) in the VIRO framework compared to competitors. Stage 5 – Identifying and analyzing external factors, Stage 6 – Fit strategy, and Stage 7 – Drawing the strategic roadmap.

This research aimed at enhancing urban resilience strategic planning in Tehran's historic residential districts, employs a multifaceted approach that combines both the Delphi method and MetaSWOT analysis. This study is structured into three key stages as outlined in Fig. 1. Initially, the study employed the Delphi method to gather expert opinions and insights. This method proved instrumental in identifying key indicators of physical and social resilience within Tehran's historical fabric, leveraging the collective intelligence of experts through rounds of questionnaires to refine understanding and consensus on the subject matter. Following this foundational work, the research advanced by employing the MetaSWOT technique, which guided the development of a strategic plan for enhancing the resilience of residential neighborhoods within Tehran's historical context. Together, these methodologies provide a robust framework for strategic planning aimed at bolstering urban resilience in Tehran's historic residential districts.

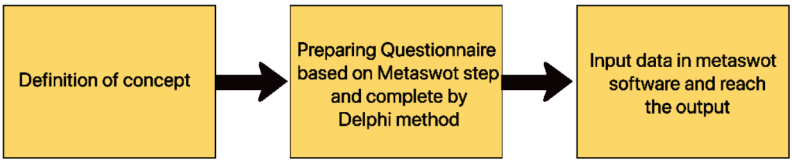

Fig. 1. Main phases of the methodology

3 Definition of Concepts

3.1 Resiliency

The term "resilience" in the Oxford culture refers to the ability of people or things to quickly achieve a better state after adverse events such as shock, damage, etc. It also means the ability of materials to return to their original state after bending, stretching, or compression [10]. The word "resilience" is derived from the Latin word "Resilio", which originally meant "to return to the original state" [11]. Holling used this term for the first time in 1973 in ecological studies [12]. He defines resilience as the level of system resistance and its ability to absorb change and disturbance while maintaining the relationship between the population or system variables [13]. Holling's (1973) major contribution lies in using the term resilience to describe dynamic equilibrium, encompassing what could exist in various spaces [14]. This perspective on resilience later became known as "ecological resilience" [15]. In general, ecology is a scientific field that conceptualizes

itself within the framework of systems [14]. After Holling, the term "resilience" evolved in the fields of materials science, ecology, and environmental studies and became conceptually available for use by professionals, planners, and academics. In such a way, resilience has been defined as the system's ability to return to a stable state after any disturbance in its performance or as the system's ability to absorb forces with minimal disruption to its functionality [16]. Figure 2 illustrates the evolution path of the concept of resilience across various sciences and disciplines.

3.2 Urban Resilience

The concept of urban resilience, originating from ecological sciences, poses challenges in its introduction and explanation as an objective approach to urban planning [5]. Urban resilience refers to the ability of cities to adapt, recover, and rebuild quickly in the face of various pressures, shocks, and disasters [11]. Assessing urban resilience not only helps to identify potential vulnerabilities and risks in advance, but also guides urban planning and construction, and improves the resilience and adaptive capacity of cities, thus mitigating losses caused by disasters [11]. Urban resilience, or flexibility, is generally defined as the capacity of an urban system or region to absorb and adapt to various shocks and stresses, a role increasingly vital as urban spaces become central to communal life [17]. A resilient city is a sustainable network of physical systems and human communities [18]. The built and natural components of the city's physical systems include roads, buildings, infrastructure, communications, and energy supply facilities, as well as water paths, soil, topography, geography, and natural systems [19]. During disasters, resilient communities must ensure the sustainability of physical systems, guide activities through social and institutional structures, and enhance capacities to survive, function, and adapt to economic and social changes in adverse conditions [20]. The resilience of cities hinges on the coordination between built and social systems, where their interaction plays a crucial role in maintaining functionality and tolerating stressful conditions during a disaster [21].

If the physical systems, like the body of the city, collapse, other systems will not be able to continue functioning. Similarly, if the social system, as the city's brain, fails, the city's performance cannot be considered resilient to disasters. Vulnerable communities and cities are not resilient to disasters; conversely, taking measures to reduce vulnerability alone is not sufficient for cities to become resilient to disasters. Resilient cities are built based on the lessons learned from past disaster experiences in urban environments. They may bend under the forces of hazards but do not break. In resilient cities, fewer buildings should collapse, there should be fewer power outages, households and businesses should be less exposed to risk, and there should be fewer casualties and injuries, there should be fewer communication disruptions and less discord, decentralization, and dispersion of networks, both economically and socially, are important characteristics of resilient cities [22]. The historical fabric and residential neighborhoods of a city encapsulate its history and identity, showcasing enduring social bonds. Recognized as the city's living spirit in architecture and urban planning, it bears witness to significant events and generations' impacts. With modernity, the challenge of social resilience grows, highlighting the importance of neighborhoods in societal resilience. These areas within the historical fabric are key to maintaining the city's authenticity and identity.

3.3 Physical and Social Resilience

The physical dimension is key to assessing community resilience, emphasizing the importance of building robustness, population density, service and emergency access, land use, and open space conditions during disasters [23]. If attention to social aspects of resilience is not more important than attention to physical and infrastructural aspects in crisis management, it is at least equally significant [24]. In a place where crime, homelessness, unemployment, and discussions related to inadequate nutrition and insufficient education are evident, it is no longer possible to place significant importance on disaster prevention issues [25]. Therefore, the concept of resilience has evolved gradually, shifting attention from its initial ecological concept towards a social-ecological concept, and eventually, towards a social concept [26]. Social resilience, a term first introduced by Adger, is defined as the capacity of groups or communities to cope with external stresses and disturbances brought about by social, political, and environmental changes [27]. He defines social resilience as the capacity of groups or communities to cope with external stresses and disturbances in the face of social, political, and environmental changes [28]. Social resilience encompasses the ability of individuals and social groups to adapt to environmental changes, essentially enabling society to restore balance or respond positively to adversities [26].

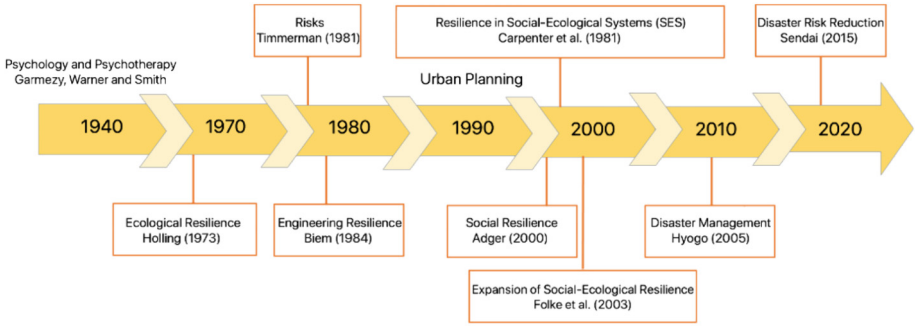

Fig. 2. Evolutionary trajectory of the concept of resilience in various disciplines

3.4 Neighborhood Resilience

Neighborhood resilience is defined as the "ability of a neighborhood to adapt to internal and external social, economic, and environmental pressures for strengthening and enrichment." In addition to defining neighborhood resilience, understanding in which context neighborhood resilience can be implemented is crucial. Often, resilience is defined as the ability to survive disasters such as earthquakes, and therefore, the necessity for the rapid ability to relocate for a return to the community is observed. However, resilience can be considered a response to gradual stresses such as climate change. Although the main characteristics of resilience may be similar, they are identified in different areas and may emphasize various dimensions of social, environmental, and systematic factors. Therefore, resilience has two characteristics: inherent capability for good performance during

crisis times and adaptability and resilience to ineffective responses during disasters [25]. Creating resilience in neighborhoods is considered neighborhood empowerment. This empowerment may be achieved by encouraging neighborhoods to establish their specific resilience indicators. Resilience, from this perspective, does not come about deeply; rather, it can positively impact the stability and preservation of strong neighborhoods.

Figure 3 provides a general overview of the conceptual framework of the research based on the theoretical literature under consideration.

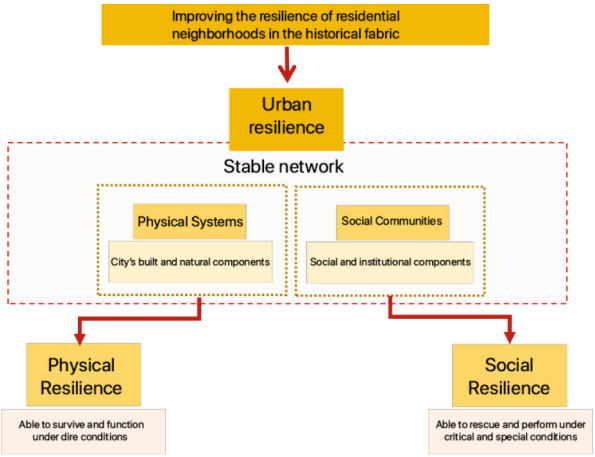

Fig. 3. Overview of the conceptual framework

4 Introduction of the Study Area

The city of Tehran spans an area of over 700 km^2, situated between 35° and 31 min to 35° and 57 min north latitude and 51° and 4 min to 51° and 47 min east longitude. The city is bounded to the north by the Alborz Mountain range, to the east by Lavasanat, to the west by Karaj, and to the south by Varamin. From a political subdivision perspective, Tehran is divided into 22 districts, 123 neighborhoods, and 354 blocks [29].

Historically, during the Tahmasbi period, Tehran comprised five neighborhoods: Sangalaj, Bazaar, Oudlajan, Imamzadeh Yahya, and Chaleh Meydan (Abshar). Presently, these neighborhoods are located within District 12 of Tehran Municipality. Therefore, in this study, with an emphasis on residential neighborhoods, research has been exclusively conducted in other neighborhoods excluding the Bazaar. Figure 4 illustrates the location of the study area.

Sangalaj, one of Tehran's oldest neighborhoods, is bounded by Amir Kabir Street (north), Molavi Street (south), Vahdat-e Eslami Street (west), and Khayyam Street (east), neighboring Oudlajan and Bazaar to the east. Home to a diverse population, it had 26,829 people across 8,814 households in 2016, with a gender distribution of 50.43% males (13,529) and 49.57% females (13,300).

Oudlajan, bounded by Shah Mosque (north), Bozarjomhori Shahri and Pamenaar/Amir Kabir Streets (south), and extending from Golestan Palace to Naser Khosrow, also includes Toopkhaneh Square. The 2016 census reported 2,932 people in 977 households for Pamenaar, with a gender split of 54.4% males (1,598) and 45.6% females (1,334).

Imamzadeh Yahya is bordered by Amir Kabir Street (north), 15th Khordad Street (south), Mostafa Khomeini Street (west), and Rey Street (east), with a 2016 population of 14,024 (52.22% males, 47.78% females) across 4,562 households. Chaleh Meydan (Abshar) is defined by Amir Kabir Street (north), Mahalati Street (south), Rey Street (west), and 17th Shahrivar Street (east), housing 22,250 people (49.7% males, 50.3% females) in 7,380 households in 2016.

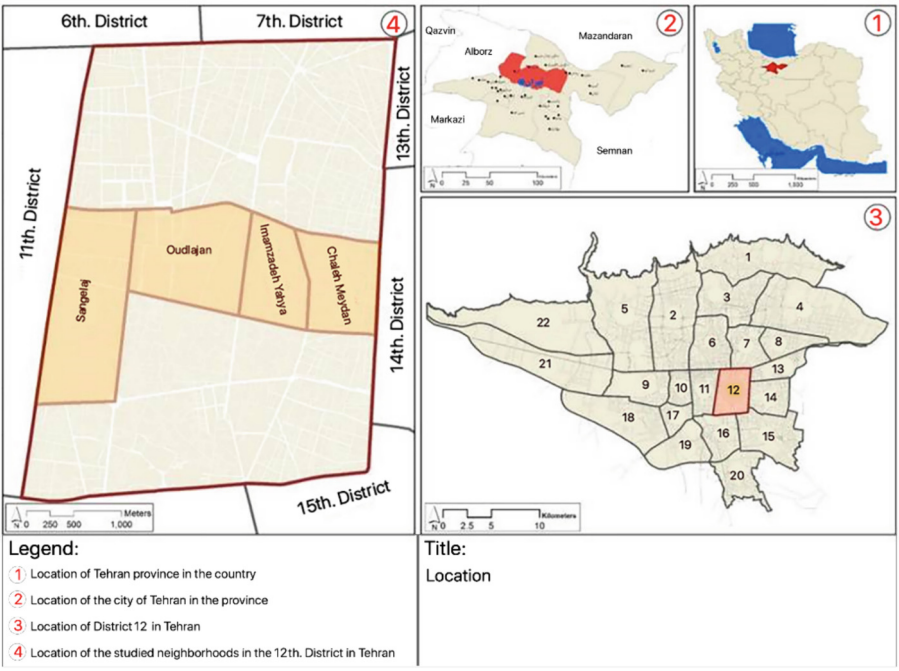

Fig. 4. Location of the study area

5 Findings

To obtain precise information required for the research, a questionnaire aligned with the steps of the MetaSWOT technique was prepared and provided to the experts. In this section, the Delphi method was employed with the involvement of 10 experts including urban planners, technicians, and academics who possessed knowledge about the MetaSWOT technique and had the necessary information regarding the conditions of the research areas. A 100% response rate was achieved, and the duration of the Delphi method was two weeks, during which consensus was reached in the second collective round, serving as the criterion for action. The implementation of the Delphi method occurred in seven stages, outlined as follows:

5.1 Stage One: Determining Research Objectives and Prioritization

In this stage, the research objectives were identified and aligned into four main categories. The experts' opinions were obtained to prioritize these objectives. The results obtained are presented in Table 1, which is available for review.

Table 1. Research Objectives Prioritization

Objectives	Priority
Enhancement of physical resilience in historical residential neighborhoods	High
Enhancement of social resilience in historical residential neighborhoods	High
Determination of the relationship between physical-social resilience components	Medium
Identification of conditions and factors influencing the resilience of residential neighborhoods	High

5.2 Stage Two: Identification and Rating of Resources and Capabilities

In this stage, utilizing the Delphi results for refining the research criteria and indicators, the adjustment questionnaire was developed. While obtaining expert opinions regarding the identified resources and capabilities, each item was scored to ensure that the total scores did not exceed 100. The obtained results are presented in Table 2:

Table 2. Scores of resources and capabilities

Resources and Capabilities	Score	Resources and Capabilities	Score
Sense of Belonging in Residents	5	Form and Fabric	4
Neighborhood Identity	5	Building Quality	9
Level of Social Interactions	5	Permeability	9
Social Cohesion	7	Road Width	7
Quality of Life	6	Number of Intersections	5
Prosperity	4	Ease of Access	6
Security	4	Emergency Evacuation Areas of Neighborhoods	10
Social Networks	9	Location of Stormwater Drainage Systems	5

5.3 Step Three: Identification of Competitive Dimensions

Since a competitive map will be drawn in the subsequent stages, it is necessary to categorize the factors related to resources and capabilities into two competitive dimensions. Considering the research objectives and the extracted resources and capabilities, competitive dimensions were categorized into two dimensions: physical and social.

Among the historical neighborhoods in Tehran, Sangalaj was considered as the base neighborhood, and other neighborhoods were considered as competitive neighborhoods. In other words, the competitors of Sangalaj neighborhood, in the order entered into the software, include Oudlajan, Imamzadeh Yahya, and Chaleh Meydan. The status of this neighborhood in comparison with other neighborhoods is presented in Table 3. By inputting the information from this table into the software, the competitive map of this neighborhood with other neighborhoods, along with the competition results in the form of a chart and table, will be obtained.

The competitive map illustrates the comparison of resources and capabilities of four neighborhoods based on two factors: social and physical dimensions. To prepare this map, one neighborhood is considered the main one, and the others are compared to it. This map is shown in Fig. 5, which presents the data from Table 3.

The results of the competitive map show that Chaleh-Meydan and Sangalaj have the same rating in the social dimension, positioned between two other neighborhoods: one unit lower than Oudlajan and one unit higher than Imamzadeh Yahya. Regarding physical dimension, Oudlajan and Imamzadeh Yahya are rated the same, slightly lower than Sangalaj and one unit higher than Chaleh-Meydan.

Table 3. Comparison of resources and capabilities in Sangalaj with other neighborhoods

Resources and Capabilities	Oudlajan	Imamzadeh Yahya	Chaleh Meydan
Sense of Belonging in Residents	Approximately Equal	Approximately Equal	Higher
Neighborhood Identity	Approximately Equal	Approximately Equal	Higher
Level of Social Interactions	Lower	Lower	Higher
Social Cohesion	Approximately Equal	Approximately Equal	Higher
Quality of Life	Higher	Higher	Higher
Prosperity	Lower	Lower	Approximately Equal
Security	Approximately Equal	Approximately Equal	Higher
Social Networks	Approximately Equal	Approximately Equal	Higher
Urban Form and fabric	Higher	Much Higher	Lower
Building Quality	Lower	Much Higher	Higher
Permeability	Lower	Much Higher	Higher
Street Width	Lower	Much Higher	Higher
Number of Intersections	Higher	Much Higher	Lower
Accessibility	Approximately Equal	Approximately Equal	Approximately Equal
Emergency Evacuation Zones	Much Lower	Much Lower	Lower
Location of Recreational Areas	Lower	Higher	Much Lower

5.4 Stage Four: Evaluation of Resources and Capabilities Based on the VIRO Criteria

In this stage, the identified resources and capabilities of each neighborhood are examined in comparison with other competitors. The VIRO criterion, evaluates the four elements of Value (V), Rarity (R), Imitability and Non-substitutability (I), and Organization of internal resources and capabilities (O) in the VIRO framework compared to competitors.

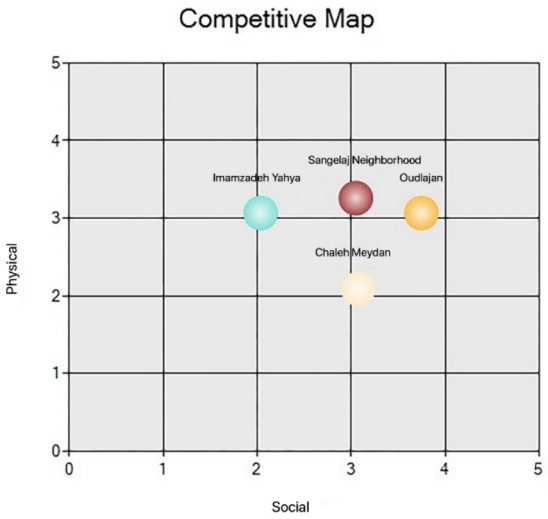

Fig. 5. Competitive map of Sangalaj neighborhood and other researched neighborhoods

Following the explanations provided in the MetaSWOT software, Rarity implies "our competitors do not have this factor," Imitability means "our competitors cannot easily develop this factor," and Non-substitutability and Organization signify "we benefit from this factor in profit-oriented decision-making." Expert opinions regarding the evaluation of these aspects are outlined in Table 4.

Table 4. Evaluation of resources and capabilities

Resources and Capabilities	Rarity	Inimitability	Non-substitutability
Sense of Belonging in Residents	Completely Disagree	Disagree	Agree
Neighborhood Identity	Completely Disagree	Agree	Agree
Level of Social Interactions	Disagree	Completely Disagree	Neutral
Social Cohesion	Disagree	Disagree	Agree
Quality of Life	Completely Disagree	Disagree	Neutral
Livability	Disagree	Disagree	Neutral

(*continued*)

Table 4. (*continued*)

Resources and Capabilities	Rarity	Inimitability	Non-substitutability
Security	Completely Disagree	Disagree	Agree
Social Networks	Completely Disagree	Disagree	Agree
Urban Form and Structure	Disagree	Agree	Agree
Building Quality	Completely Disagree	Disagree	Agree
Permeability	Disagree	Disagree	Agree
Street Width	Disagree	Disagree	Agree
Number of Intersections	Neutral	Agree	Neutral
Accessibility	Completely Disagree	Disagree	Agree
Emergency Evacuation Areas	Disagree	Completely Disagree	Agree
Location of Water Features	Disagree	Disagree	Disagree

5.5 Stage Five: Identification and Analysis of External Factors

In this stage, in addition to identifying external factors, the stability and dynamism (weight), the level of impact, the likelihood of occurrence, and the degree of urgency for each of these factors are evaluated.

Table 5. Analysis of external factors

Factors	Weight	Impact	Likelihood of Increase	Degree of Urgency
Citizen education	Very important	Strong	Moderate	Immediate
Conducting drills at different time intervals	Very important	Strong	Low	Soon
Consideration of incentive policies for resilience	Very important	Strong	High	Very soon
Natural disaster occurrence (earthquake, flood, etc.)	Important	Very weak	High	Long term
Occurrence of non-natural crises (war, airstrikes, etc.)	Important	Very weak	Moderate	Long term
Resource management	Very important	Strong	Moderate	Soon
Making appropriate and timely decisions and solutions	Very important	Strong	Moderate	Very soon

Following the explanations provided in the MetaSWOT software, “Weight” means “How important are these factors compared to average challenges?”, “Impact” means

"How strongly do these factors affect success?", "Likelihood of Increase" means "The likelihood of this factor occurring during the planning period," and "Degree of Urgency" means "The amount of need for this factor." Expert opinions on the evaluated items in Table 5 are as follows.

5.6 Stage Six: Alignment Strategy

– Fit between Resources and Capabilities with External Factors

Experts evaluate how resources and capabilities affect external factors, calculating strategic alignment by adapting internal or external factors. This stage aims to understand how resources and capabilities support opportunities and mitigate threats. The findings of the alignment examination by experts are outlined in Table 6.

– Alignment Between Resource and Capability Factors and Research Objectives

Table 6. Alignment between resources and capabilities and external factors

External Factors Resources and Capabilities	Training	Maneuver	Incentive Policy	Natural Disasters	Crisis Occurrence	Resource Management	Decision-Making
Sense of Belonging in Residents	W	N	W	VW	W	S	N
Neighborhood Identity	VW	N	W	VW	W	S	N
Level of Social Interactions	N	S	S	VW	W	S	S
Social Cohesion	S	S	S	VW	W	S	S
Quality of Life	S	W	S	VW	W	S	N
Well-being	W	N	W	VW	W	W	N
Security	VW	S	W	VW	VS	S	S
Social Networks	S	S	S	VW	W	S	S
Form and Structure	W	W	S	S	S	N	N
Building Quality	W	W	VS	VS	VS	S	N
Permeability	W	W	S	VS	VS	S	N
Road Width	W	W	S	VS	VS	S	W
Number of Intersections	W	N	N	S	S	N	VW

(*continued*)

Table 6. (*continued*)

External Factors Resources and Capabilities	Training	Maneuver	Incentive Policy	Natural Disasters	Crisis Occurrence	Resource Management	Decision-Making
Ease of Access	N	W	N	S	S	N	N
Emergency Evacuation Areas in Localities	S	S	VW	VS	VS	W	S
Position of Hazardous Land Uses	S	S	VW	VS	VS	W	S

N = Neutral, S = Strong, W = Weak, VW = Very Weak, VS = Very Strong

At this stage, experts evaluate how resources and capabilities influence research objectives. The process involves aligning internal factors with these objectives to determine their support level. Strategic alignment is thus assessed based on this criterion. The extent of support for research objectives by resources and capabilities is the primary focus. The findings from this alignment evaluation are summarized in Table 7.

Table 7. Alignment between resources and capabilities and research objectives

Research Objectives Resources and Capabilities	Enhancement of Physical Resilience	Enhancement of Social Resilience	Determination of the Relationship between Resilience Components	Identification of Effective Conditions and Contexts
Sense of Belonging in Residents	Strong	Very Strong	Strong	Strong
Neighborhood Identity	Strong	Very Strong	Strong	Strong
Level of Social Interactions	Neutral	Very Strong	Neutral	Strong
Social Cohesion	Strong	Very Strong	Neutral	Strong
Quality of Life	Weak	Strong	Strong	Neutral
Livelihood	Weak	Strong	Neutral	Neutral
Security	Weak	Strong	Weak	Neutral

(*continued*)

Table 7. (*continued*)

Research Objectives Resources and Capabilities	Enhancement of Physical Resilience	Enhancement of Social Resilience	Determination of the Relationship between Resilience Components	Identification of Effective Conditions and Contexts
Social Networks	Strong	Very Strong	Neutral	Strong
Form and Structure	Very Strong	Neutral	Strong	Strong
Building Quality	Very Strong	Weak	Weak	Strong
Permeability	Very Strong	Weak	Very Weak	Strong
Road Width	Very Strong	Weak	Weak	Strong
Number of Intersections	Strong	Strong	Strong	Neutral
Accessibility Ease	Strong	Neutral	Neutral	Strong
Emergency Evacuation Areas	Very Strong	Neutral	Very Weak	Strong
Location of Hazardous Land Uses	Very Strong	Very Weak	Very Weak	Strong

5.7 Stage Seven: Drawing the Strategic Map

In the strategic map, resources, capabilities, and external factors are evaluated using three criteria: proximity to external factors, directional orientation, and bubble size. Blue bubbles signify internal resources and capabilities. The X-axis measures scarcity, non-imitability, and organizational fit, while the Y-axis assesses the strategic fit level of the factors [8]. Factors leaning to the right are relatively valuable, rare, non-imitable, and irreplaceable, possessing strategic fit. Those leaning upwards have a high degree of strategic fit. The size of the bubbles indicates the degree of their fit with the objectives [23].

External factors, depicted by orange bubbles on the strategic map, illustrate factor power on the X-axis and necessity through bubble size, with proximity highlighting internal support for external factors [8]. In general, for both categories of bubbles representing resources and capabilities, as well as external factors, placement in the upper-right position indicates the highest score and rating [23]. At this stage, after analyzing data across six stages, a unified strategic map for the studied neighborhoods was created, reflecting shared objectives, resources, capabilities, and external factors, as depicted in Fig. 6.

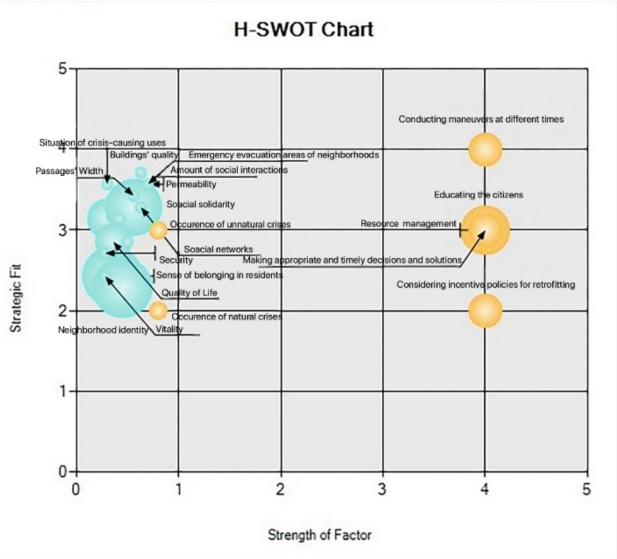

Fig. 6. Strategic map of Tehran's historic residential districts

5.8 Analysis of Strategic Map

Analysis of strategic map for residential areas based on the following criteria:

Proximity of Resources and Capabilities to External Factors

The closer the resources are aligned with opportunities, the more indicative it is of favorable conditions. In the extracted strategic map, depicted in Figs. 5 and 6, the available resources, and capabilities in the neighborhood, in both social and physical dimensions, are concentrated on the left side of the chart. This indicates a considerable distance from potential opportunities, such as providing education to residents, conducting maneuvers at different times, considering incentive policies for resilience, and adopting timely and proportionate decisions and solutions. On the other hand, the proximity of threats, including the occurrence of natural disasters (earthquakes, floods, etc.) and non-natural crises (war, aerial attacks, etc.), to resources and capabilities reflects the lack of necessary preparedness in these areas to confront threats.

Horizontal and Upper Direction of Factors, and Bubble Size

For a detailed examination, Table 8 shows the placement of each internal and external factor and the size of the bubbles.

Blue Bubbles on the Chart Representing Resources and Capabilities

The blue bubbles on the chart represent resources and capabilities, and their placement relative to the X-axis (less than 1) indicates that all these factors are imitable and non-scarce, accessible by other areas. The positioning of these bubbles concerning the Y-axis (all above the number 2) suggests that, in terms of strategic compatibility, they have high ratings. The highest of these are related to social networks, permeability, and emergency evacuation areas, indicating a high strategic fit for these aspects. It's worth mentioning that other factors also show a significant and appropriate strategic fit. The

Table 8. Placement and Size of the Resource and Capability Bubble and External Factors

	Resources and Capabilities/External Factors	X-Axis Coordinates	Y-Axis Coordinates	Bubble Size
Resources and Capabilities	Sense of Belonging in Residents	0.35	2.43	6.375
	Neighborhood Identity	0.45	2.29	6.375
	Level of Social Interactions	0.30	3.14	3.75
	Social Cohesion	0.56	3.29	6
	Quality of Life	0.36	2.86	3.25
	Livability	0.28	2.43	1
	Security	0.27	2.71	0.5
	Social Networks	0.63	3.58	6.35
	Form and Structure	0.40	3.14	0.58
	Building Quality	0.63	3.71	2.35
	Permeability	0.72	3.57	3.26
	Road Width	0.56	3.43	2.18
	Number of Intersections	0.50	2.86	0.62
	Accessibility Ease	0.42	3.14	1
	Emergency Evacuation Areas of Districts	0.70	3.57	2.54
	Hazardous Land Use Areas	0.30	3.34	1.08
External Factors	Education for Citizens	4	3	5
	Conducting Maneuvers at Different Times	4	4	3
	Consideration of Incentive Policies for Resilience	4	2	3
	Occurrence of Natural Disasters	0.80	2	1
	Occurrence of Non-natural Crises	0.80	3	1
	Resource Management	4	3	3
	Adoption of Timely and Proportional Decisions and Solutions	4	3	3

size of the bubbles serves as a measure, and the highest-scoring factors in terms of research objectives are the sense of belonging in residents, neighborhood identity, social cohesion, and social networks. Following these, factors like quality of life, building quality, permeability, road width, and emergency evacuation areas also exhibit the highest alignment with research objectives.

Orange Bubbles on the Chart Representing External Factors

The orange bubbles on the chart represent external factors, and their placement relative to the X-axis indicates the strength of these factors in achieving the research objectives. All identified opportunities, including education for citizens, conducting maneuvers at different times, considering incentive policies for resilience, resource management, making timely and proportional decisions, show significant strength toward achieving research objectives. In terms of strategic compatibility, conducting maneuvers and education for citizens, followed by making timely decisions and solutions, resource management, and incentive policies, exhibit relatively good strategic alignment. The bubble size indicates the degree of urgency, with education for citizens having the highest score among all factors.

6 Conclusion

The creation of resilience in neighborhoods is considered synonymous with empowering localities. This empowerment may be achieved by encouraging neighborhoods to establish their resilience indicators. Resilience, from this perspective, does not emerge deeply; instead, it can positively impact the stability and preservation of strong localities. In other words, neighborhood resilience contributes to improving the quality of place and life, both qualitatively and quantitatively. It also leads to the construction of more resilient structures in future crises and, due to emotional bonds, increased participation in problem-solving and, consequently, care for the place.

In this research, the MetaSWOT software has been utilized to develop a strategic plan for physical and social resilience in historical residential neighborhoods. The application of the MetaSWOT method, as a modern technique, is rarely seen in urban planning research. The six-step process of this technique was executed, and the strategic map of the researched neighborhoods was extracted in the seventh step. According to the obtained map, the sense of belonging in residents, neighborhood identity, social cohesion, quality of life, and social networks are of high importance for enhancing social resilience. In physical resilience, building quality, permeability, road width, and emergency evacuation areas also exhibit the highest level of alignment with research objectives.

Since residential neighborhood resilience is not possible without making the community resilient, the enhancement of resilience in historical residential neighborhoods is dependent on social resilience in these areas. Therefore, the resulting strategic map emphasizes the necessity of focusing on the social aspect. In this regard and considering the importance of citizen participation in creating resilient communities, citizen education, considered as an external factor, holds significant importance.

This research aims to draw attention to the importance of resilience in historical residential neighborhoods in Tehran, which have been neglected for a considerable period. Based on the research findings, the following suggestions are proposed for improving resilience in historical neighborhoods:

- Involving relevant organizations, such as municipal authorities, in intervention, with a focus on citizen education.
- Increasing citizen participation in the resilience-building process through citizen education.
- Optimizing and redefining the practical application of social dimensions in residents' urban life and outlining basic principles in social resilience through annual reports and establishing a task force for its analysis in neighborhood centers to monitor resilience goals.
- Organizing effective and practical training courses and drills to assess the preparedness of citizens.
- Reducing vulnerability levels and returning to pre-crisis conditions in case of any incident in these neighborhoods.

Ultimately, by formulating principles and policies for resilience in residential neighborhoods, especially those with historical structures, a better outlook for the future of the country's cities can be envisioned. In conclusion, researchers and scholars interested in urban resilience are encouraged to explore other dimensions of resilience at the intermediate and local levels, especially in residential neighborhoods, in future studies.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process. During the creation of this document, the authors engaged with ChatGPT to polish the language and improve its clarity. Following the use of this technology, they carefully reviewed and modified the manuscript as necessary, taking full accountability for the final content of the publication.

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Gamification: A Catalyst to Achieve Carbon-Neutral Cities

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Abstract. In addressing the challenges of climate change, it is crucial to develop effective strategies for implementing climate policies. This article aims to provide a comprehensive overview of gamification's potential as a tool for fostering sustainable communities and achieving carbon-neutral cities. Based on state-of-the-art literature, it examines the impact of game apps and gamified places (Urban gamification) in tackling climate change. The article is structured in three main stages: an extensive literature review to pinpoint scholarly works relevant to gamification and carbon neutrality, an analytical synthesis to examine gamification's impact on sustainable urban development, and a comparative analysis to evaluate the effectiveness of game apps and gamified places in promoting carbon-neutral cities. The article introduces gamification as a catalyst for building sustainable communities and advancing toward carbon-neutral cities. It highlights the need for empirical research and practical trials to choose the most suitable gamification approach, considering societal preferences, method legitimacy, and community acceptance.

Keywords: Gamification · Carbon-neutral Cities · Game App · Gamified Place · Urban Gamification · Sustainability

1 Introduction

Humankind must proactively address the severe challenges caused by climate change [1]. Climate change caused by excessive carbon emissions has become one of the most severe problems facing the world's ecosystems and human society [2]. The causes of global warming are related to socioeconomic activities [3], and this human-caused climate change needs human efforts and knowledge to change the socio-technical and socio-ecological systems we have constructed [4].

As the climate crisis seriously threatens ecologic, economic, societal, and cultural systems, urgent action toward reducing greenhouse gas (GHG) emissions and coping with its impacts in the near term is fundamental [5]. As of February 2021, 124 countries worldwide have declared their intention to become carbon neutral and achieve net-zero carbon emissions by 2050 or 2060 [1].

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Due to the increasing urban population and the amount of time people spend in buildings, cities are responsible for significant amounts of carbon emissions [1]. Cities have become primary actors in climate change and are increasingly setting goals aimed at net-zero emissions [6] and playing a key role in achieving the climate goals of the Paris Agreement [7]. Despite the limitations in GHG reduction capability, numerous cities have committed to reaching carbon neutrality within a certain time, and sometimes before national carbon neutrality targets [8]. In addition to international and national efforts [9], consortiums such as Cites40, Covenant of Mayors, and ICLEI have been organized to advance the goal of carbon neutrality and general carbon reduction actions in their member cities [8]. Additionally, the Carbon Neutral Cities Alliance (CNCA) comprises foremost global cities committed to attaining carbon neutrality within the next 10 to 20 years [10]. They strive to foster concepts that promote societal well-being, communal destinies, and collective welfare [11].

Consensus, intelligence, and actions are requirements for the pathway toward a greener society [9] and carbon-neutral cities. For instance, sustainable food, energy, and water resource consumption can significantly reduce GHG emissions [12]. Hence, the role of citizens in adopting sustainable practices in food, energy, and water consumption becomes crucial in reducing GHG emissions and achieving the goals of the carbon-neutral city network.

Therefore, guiding people to put low-carbon actions into practice more effectively is crucial to the success of long-term environmental sustainability [2]. Successful nudging for such behaviors requires an intimate knowledge of messaging that resonates and inspires actions in households [12]. Although pro-environmental behavior is often considered commendable, in many cases it is more unprofitable, unpleasant, time-consuming, or effort-consuming than harmful behavior to the environment [2]. Nowadays, online applications aim to attract citizens to discuss issues related to the environment to enhance the process of participation [13]. Today, our reality and lives are increasingly game-like, not only because games have become a pervasive part of our lives, but also because activities, systems, and services are increasingly gamified [14]. Thus, integrating engaging online platforms with effective messaging strategies becomes imperative in encouraging citizens towards more profitable and enjoyable pro-environmental behaviors, paving the way for a sustainable future.

The insights provided by recent studies highlight gamification's pivotal role in promoting low-carbon behaviors and offer practical guidance for the design of related green and low-carbon platforms [2]. Therefore, in the quest for building sustainable communities and achieving Carbon Neutral Cities (CNC), gamification has emerged as a powerful tool. This study discusses game apps and gamified places and their significant contributions to fostering sustainable communities in the journey toward achieving carbon neutrality. It underscores the role of gamification in deepening our understanding of its influence on the development of carbon-neutral cities. By drawing on scientific and scholarly works, the article provides a comprehensive literature overview, offering an analytical synthesis and a comparative analysis, showcasing the potential of gamification as a powerful tool in the pursuit of sustainability. Based on this approach, the study

poses a main research question: How does gamification through game apps and gamified places contribute to fostering sustainable communities within the framework of achieving carbon-neutral cities?

This study unfolds through three main stages, beginning with an extensive literature review aimed at identifying scholarly works pertinent to gamification and carbon neutrality. This is followed by an analytical synthesis that delves into the impact of gamification on sustainable urban development, exploring how gamification can influence and propel the transition toward more sustainable, carbon-neutral urban environments. The final stage comprises a comparative analysis assessing the effectiveness of game applications and gamified places in fostering carbon-neutral cities, offering insights into the practical applications and potential benefits of gamification in achieving sustainable urban goals.

2 Methodology

The research aims to explore the intersection between gamification strategies and the pursuit of carbon neutrality within sustainable communities. To achieve this goal and address the research question, the study adopts a structured approach. Each stage builds upon the previous one, ensuring a comprehensive exploration of how gamification can contribute to sustainability efforts. The process is detailed in Fig. 1 as follows:

Stage 1- Identifying Relevant Literature
In this step, a review was conducted on a set of scientific publications by researching through several databases. These databases included ScienceDirect, Scopus, Web of Science, and Google Scholar. The adopted approach involved searching using keywords such as gamification, carbon neutral*, communit*, sustainabl*, and climate*. The review process was narrowed down to papers relevant to the objective of this study by screening in two steps: first, the abstract, and then the whole article. This approach identified 41 relevant papers which are categorized into two main groups based on the factors discussed. These categories are crucial for answering the research question. The first category relates to carbon neutrality and sustainable communities. The second category, which contains many of the articles, explores the role of gamification in achieving carbon-neutral cities. By reviewing the articles obtained in this stage, significant topics were identified, which are detailed in the subsequent sections.

Stage 2- Analytical Review and Synthesis
This stage is designed to synthesize existing knowledge, involving the definition of the concepts of carbon-neutral cities and gamification in two distinct aspects: game apps and gamified places. It also entails identifying key elements essential for achieving carbon neutrality within sustainable communities. Additionally, this stage recognizes the potential impacts of gamification on achieving carbon-neutral cities and their impact domains. In alignment with the social approach of this article, only factors within the social impact domain will be selected, and their explanation will highlight the relationship between these elements and game apps and gamified places.

Stage 3- Concluding Synthesis
The final stage combines the information gained from the previous stage and addresses the research question in two parts: one part illustrates a diagram explaining how gamification, in two aspects—game apps and gamified places—contributes to achieving carbon-neutral cities; the other part involves a discussion comparing these two aspects of gamification for selection.

In summary, this paper presents a model for using gamification to guide communities toward carbon neutrality. It provides a structured framework and actionable steps to effectively employ gamification strategies aimed at fostering sustainable behaviors and increasing eco-social awareness, ultimately contributing to the collective goal of mitigating carbon emissions.

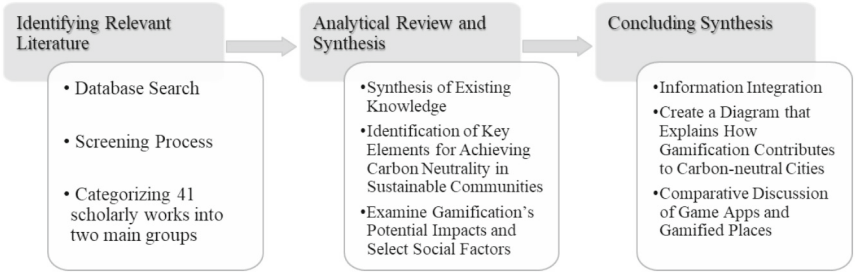

Fig. 1. Phases of the Research Methodology

3 Carbon-Neutral Cities

Carbon neutrality refers to net-zero carbon dioxide (CO2) emissions [15], which can be achieved by balancing the total amount of carbon dioxide or GHG emissions produced directly or indirectly by a country, company, product, activity, or individual over a certain period via carbon offset or removal initiatives [1]. Carbon neutrality will greatly slow global warming and solve our energy crisis, with accompanying benefits to air quality, ecological recovery, and landscape beautification [15]. Carbon neutrality is a mutable idea [11], and it is not an ultimate phase but a temporary status, which constantly fluctuates with annual carbon emissions [9].

The academic discourse on the definition of a carbon-neutral city is sparse, primarily exploring it through urban climate concepts, emission accounting scopes, analysis of climate policy documents, stakeholder dialogue, and definitions provided by cities' climate networks [7]. CNCs generate a net zero increase in emissions by reducing primary carbon emissions and offsetting residual emissions [9]. CNCs are urban areas that achieve carbon neutrality through a coordinated effort from various stakeholders, including local governments, citizens, businesses, and civil society organizations [16].

C40 Cities' outline of a carbon-neutral city outlines four benchmarks for achieving carbon neutrality: 1. Net-zero GHG emissions from fuel use in buildings, transport, and industry, 2. Net-zero GHG emissions from the use of grid-supplied energy, 3. Net-zero

GHG emissions from waste treatment generated within the city boundaries, and 4. Where a city accounts for additional sectoral emissions in their GHG accounting boundary, net-zero GHG emissions from all additional sectors in the GHG accounting boundary [8, 9].

According to the Global Protocol for Community-Scale GHG Emission Inventories, a particular city's GHG emissions can be estimated within multiple scopes [9]. While there isn't a universally accepted definition, there's no standard interpretation of "net zero" concerning individual entities [6]. Therefore, more clarity is needed on the definition of the carbon-neutral city concept and especially on the role of offsetting emissions (a specific feature compared to other urban climate concepts) [7].

Based on the various definitions of carbon neutrality, achieving such a status requires a multifaceted approach involving both emission reductions and carbon offsetting. CNCs are urban regions that achieve a balance between the greenhouse gases they emit, and the amount of carbon dioxide absorbed by local natural resources, ensuring their overall carbon footprint is neutral.

3.1 Sustainable Communities to Implement Climate Policies

Sustainable community is a term that is widely used by policymakers in many countries, but what constitutes a sustainable community is often a cause of debate [17]. Creating sustainable communities is a complex task [18]. According to [19], sustainable communities are desirable, inclusive places that cater to the varied needs of current and future residents, promote environmental sensitivity, and enhance the quality of life by offering safety, thoughtful planning, equality of opportunity, and access to quality services for everyone.

Community-scale development projects aimed at minimizing fossil fuel use and greenhouse gas emissions, known as carbon-neutral communities, low-carbon communities (LCCs), renewable energy communities, and net-zero energy communities, have been advocated across various countries [20]. Therefore, a crucial responsibility of sustainable communities involves implementing climate policies and working towards achieving carbon-neutral cities, underscoring their pivotal role in addressing environmental challenges and promoting sustainability.

Communities must not only be informed about climate change but also deeply care, feel motivated, and possess the capability to actively engage in actions that mitigate climate risks for their members [21]. Thus, creating synergy in climate actions relies on scientific understandings of complex urban dynamics within a specific geographical, demographic, and cultural context and long-term partnerships among stakeholders involving city government, public or non-profit agencies, private entities, community-based organizations, and the public [9].In essence, fostering a collective commitment to climate action rooted in informed awareness, genuine concern, and collaborative engagement is key to addressing the intricate challenges posed by climate change within communities.

Achieving CNCs necessitates a multifaceted approach [16], and their pathway to carbon neutrality will be a long-term ecological, technical, and social process [9]. The complexity of governance at the city level hinders policy and plan implementation, and without involving citizens, efforts toward achieving carbon neutrality fall short [16]. It

indicates that community consideration and engagement might be an important aspect of climate action plans [6]. Some methods for promoting mitigation and adaptation synergies were recommended, including investments and community awareness [1]. Therefore, fostering eco-social awareness and active participation among citizens is a critical step towards achieving the ambitious goal of carbon neutrality in cities.

Social participation is crucial to minimize GHG emissions in all development plans, programs, and projects whether initiated by multi-lateral agencies, the government, or the private sector [3]. A comprehensive review of the literature on social participation in achieving sustainability goals highlights the significance of public education and awareness campaigns, citizen-led initiatives, partnerships between local government and community groups, and building a sense of ownership and responsibility among communities [16]. In addition, the government also encourages residents to participate in the supervision of environmental regulation policies to strengthen public recognition of the concept of low-carbon green energy, develop a low-carbon green lifestyle, increase green consumption demand, and guide enterprises to low-carbon green production [22].

Achieving an eco-friendly lifestyle, like any other lifestyle, is done by adopting habits and attitudes, in this case, ecologically conscious ones [23]. Considering lifestyle shifts as one critical transformation for achieving CNC [9], social participation, knowledge sharing, and community involvement are crucial for a successful environmental transition. These elements empower individuals and groups to make informed choices for sustainability. Cultivating this informed and active community spirit accelerates sustainable practices, fostering shared responsibility and enhancing efforts towards carbon neutrality.

Based on the previous discussion, the key that previous literature has found necessary to achieve carbon-neutral cities in sustainable communities, and their descriptions are shown in Table 1. These elements together form a comprehensive strategy for creating sustainable, carbon-neutral communities by addressing both the environmental and social aspects of sustainability.

4 Gamification

Gamification, i.e. the use of game design elements in nongame contexts [24]. Gamification is to take elements that normally operate within the game universe and apply them effectively in real situations [13]. The concept of gamification is not new, having its roots in marketing endeavors [25]. Gamification is the process of adding games or game-like elements to something (such as a task) to encourage participation [26]. The rationale is to leverage game mechanics' power for a non-entertainment purpose [24].

Gamification refers to designing information systems to afford similar experiences and motivations as games do, and consequently, attempting to affect user behavior [14]. It has been explored and used in many sectors, such as education, health and wellness, crowdsourcing, and sustainability [24]. In the context of sustainability, gamification has been applied to various areas including sustainability education, energy conservation, transportation, air quality improvement, waste management, and water preservation [27]. It means that game dynamics can be used to stimulate sustainable behaviors [24]. Games are renowned for their capacity to captivate and stimulate individuals. When participating

Table 1. Key Elements for Achieving Carbon-Neutral Cities in Sustainable Communities

Key Item Group	Description	References
Informed Communities & Collective Commitment	Fostering community knowledge alongside a unified effort towards climate policy and action	[17–20]
Community Engagement & Social Participation	Involving communities in climate action and policy decision-making	[3, 6, 9, 16]
Eco-social Awareness & Public Education	Educating the public on sustainability and eco-friendly behaviors	[1, 9, 16, 21, 22]
Sense of Ownership & Responsibility	Cultivating responsibility among individuals for environmental stewardship	[16, 22]
Lifestyle Shifts towards Sustainability	Promotes adopting sustainable habits and attitudes for ecological well-being	[9, 23]

in games, people often encounter feelings such as mastery, competence, enjoyment, immersion, or flow, all of which are indicative of intrinsically driven human behavior [14]. A relatively new concept was developed in the latter part of the 20th Century when people started to consider games to increase productivity in everyday life [28].

The gaming world is boundless [13]. Gamification mentioned in this paper refers to Serious Games, a dynamic concept that leverages game mechanics and design elements to enhance user engagement, motivation, and behavior. This article focuses on two primary categories: game apps and gamified places (urban gamification). Game apps refer to dedicated applications that incorporate gamification elements, while gamified places involve the integration of game mechanics into physical environments.

The term serious game refers to a set of methodologies that involve role play and immersive game situations for the management of diverse types of activities [29]. Gamification does not turn everything into a game, but it is about finding the monotonous activity that usually requires collaboration and engagement [28]. There are three essential steps in gamifying a specific process: Firstly, determining the goals of the activity or system. Secondly, identifying the players and categorizing them based on recognizable behavioral traits. Finally, employing suitable game elements to inspire and encourage player participation [24].

4.1 Game Apps: Enhancing Engagement and Awareness

The use of digital and online games has increased rapidly in recent years, suggesting that gaming is now part of everyday life for many [30]. Games and gamified applications hold potential as effective instruments for encouraging sustainable behaviors, especially when juxtaposed with alternative approaches to behavior modification [27]. Well-designed

digital games utilize intrinsically motivating qualities to shape human behavior, attitudes, and cognitions [31].

Studies [32] indicate that while the intervention initially spurred positive behavior changes—particularly in energy-saving actions—its impact was most significant in the short term. Engagement in these behaviors peaked at the study's midpoint but subsequently declined, leading to lower levels of engagement by the study's conclusion. This pattern underscores the necessity for ongoing support and innovative strategies to sustain and enhance the effectiveness of such interventions over time. It suggests that while initial engagement can be high, maintaining this momentum is crucial for long-term behavior change. Thus, efforts should focus on identifying methods to keep individuals motivated and engaged, ensuring that the positive changes initiated by such interventions are durable and continue.

4.2 Gamified Places: Transforming Physical Spaces

Nowadays, the idea that cities shouldn't just be smart but also playable is gaining more and more recognition [33]. Using a real city as a gamified scenario is not new [34]. Many of us have likely engaged in playful interactions with urban spaces, such as avoiding walking on pavement lines, encountering hopscotch chalk drawings on sidewalks, or hopping through them on one leg, even if just once [33].

Gamified places or urban gamification can be a way for the citizens to reclaim their right to the city, as well as a way for gamifiers to attempt to influence the behavior of the citizens by rewriting the urban spaces around them [35]. Urban Gamification claims that urban play can be instrumental in empowering citizens and helping them reappropriate public spaces [33].

Gamification can be very simple small elements, like in Stockholm where the stairs of one metro station saw little use over the escalator until each step was made into a piano key playing sounds as people stepped on the steps [28]. Similarly, examples like Volkswagen's Fun Theory aim to shape behavior through fun activities, the World's Deepest Bin makes disposing of trash enjoyable with its funny sounds, and the Speed Camera Lottery promotes safe driving by combining fines with rewards for those adhering to speed limits [33]. Furthermore, MEECO is a platform that leverages the real-world setting of a city, enabling users to use their mobile devices to log eco-friendly actions like recycling or biking, integrating digital interaction with environmental sustainability [23]. These activities revolve around strategically placing cutting-edge gadgets throughout the urban landscape, allowing them to remain there for an extended duration. The aim is to engage citizens in enjoyable or playful interactions that ultimately influence their behavior [35].

Since gaming significantly influences our cognition, behaviors, and emotions, thereby boosting our intrinsic motivation, the mentioned features allow us to utilize game mechanics and dynamics to guide citizens' behaviors as players within the urban context in a predetermined manner [36]. However, while urban gamification presents opportunities for positive behavior change and engagement, it also raises concerns. Excessive gamification may lead to the commodification of everyday life, reducing genuine interactions and autonomy. Additionally, there is a risk of reinforcing inequality if certain

groups are excluded from or disadvantaged by gamified systems. Therefore, while leveraging gamified places can promote sustainable and positive urban experiences, careful consideration of ethical, social, and equity-related implications is essential to ensure their responsible and equitable implementation.

5 Gamification for Carbon-Neutral Cities

Individual cases of implementation are not sufficient for the widespread societal transformations needed for cities to become carbon-neutral [37]. Engaging citizens with climate change is an urgent and complex issue, requiring a multifaceted approach to foster cognitive (knowing), affective (caring), and behavioral (acting) connections to the issue [5]. Goal-framing theory suggests that individuals' behaviors, influenced by hedonic, gain, and normative motivations, can significantly impact their engagement in environmentally friendly behaviors [2]. Gamification, transforming activities to offer game-like experiences, has proven effective in promoting these types of engagement with climate change, combining educational goals with behavioral change [5].

Gamification emerges as a promising strategy to encourage eco-friendly behaviors, offering an alternative to traditional methods like taxes, subsidies, and restrictions, which may have undesired effects [24, 27]. It mobilizes public participation, shifting from passive information reception to active involvement in low-carbon practices, and is seen as a useful tool for learning and sustaining engagement in non-entertaining activities. The pleasure derived from game mechanics increases willingness to participate and boosts activity levels, suggesting that gamified interactions in the environmental sector can lead to more low-carbon actions [2, 38].

Digital tools, especially smartphone apps, enable social innovation for low-carbon transitions, engaging people to act more sustainably and leveraging collective action [39]. The effectiveness of smartphone technologies as a foundation to improve community-based and citizen-based environmental monitoring is not clear [40]. While gamification shows promise in promoting low-carbon actions, its effectiveness depends on careful conception, deployment, and management to ensure maximum user involvement. Addressing this challenge requires finding ways to make adopting an eco-friendly lifestyle appealing at an individual level for broader societal benefits [2, 23, 24].

In summary, gamification stands out as a groundbreaking and impactful strategy for mobilizing individuals and communities in the crucial battle against climate change. It plays a pivotal role across a broad range of areas vital to the realization of carbon-neutral cities, as shown in Table 2. This includes fostering increased social participation, deepening education and awareness, cultivating community spirit, and encouraging shifts in lifestyle and behavioral patterns—fundamental components that this paper emphasizes for nurturing sustainable communities. Moreover, gamification extends its influence on other significant domains such as data collection and analysis, fostering innovation and creativity, boosting investments in green technologies, enhancing policy engagement and support, improving health and well-being, and advancing sustainability reporting and transparency, though these topics fall outside the scope of this discussion. By infusing everyday activities with game-like elements, gamification not only sparks interest but also cultivates a collective commitment to adopting sustainable practices. This method

stands out by transforming environmental responsibility from duty into an enjoyable pursuit, thereby overcoming the limitations of traditional, often less engaging strategies. For gamification to realize its full potential in promoting eco-friendly behaviors, it must be carefully designed, implemented, and managed to resonate with a broad spectrum of motivations and lifestyles. Looking ahead, leveraging gamification as a catalyst for environmental action offers a promising avenue to redefine our engagement with sustainability, making it more accessible, enjoyable, and ultimately, more effective.

5.1 Increasing Social Participation

Alongside technology, using different ways to increase social participation is more important than ever, and future researchers should continue to explore novel ways to achieve this [16]. Serious games have been proposed by several studies as a tool to foster civic participatory processes [41]. Games inherently increase engagement and motivation [12] and Gamification mobilizes the initiative of public participation [2]. Gamification is an effective strategy to engage more citizens in the co-creation of livable, resilient, and sustainable cities [25]. Gamification catalyzes increasing social participation in the implementation of climate policies.

Gamification can make the process of learning about carbon neutrality more engaging and accessible to the public. By turning sustainability efforts into a game, it can encourage more people to participate in activities that reduce carbon footprints. In both game apps and gamified places, community members are motivated to adopt sustainable practices, collaborate on environmental initiatives, and actively contribute to the overarching goal of achieving carbon-neutral cities.

Table 2. Potential Impacts of Gamification to Achieve Carbon-Neutral Cities

Item	Impact Domains	References
Increasing Social Participation	Social Engagement, Awareness	[2, 12, 25, 41]
Lifestyle and Behavioral Change	Social Behavior, Environmental Action	[2, 13, 24, 27, 30, 42]
Data Collection and Analysis	Governance, Urban Planning	[23, 24, 39, 40]
Education and Awareness	Education, Social Awareness	[1, 13, 27, 30, 43, 44]
Creating a Sense of Community	Community, Social Cohesion	[2, 9, 24, 30]
Innovation and Creativity	Innovation, Environmental Solutions	[13, 24, 28]
Increased Investment in Green Technologies	Business, Technology	[2, 27]
Policy Engagement and Support	Governance, Policy	[5, 24, 25]

5.2 Education and Awareness

According to the literature, among the different techniques of experiential learning, simulation games are particularly suited for providing a structured environment for learning complex problems [43]. Among the learning tools, serious games represent a very promising medium for adoption in this context [13] and have rapidly gained momentum as a method to support both knowledge transmission and development [1].

Game-based learning in simulated Serious Games creates a significantly greater potential for learning over other media [12]. Studies have shown that gamification in education can lead to improved learning outcomes, including increased knowledge retention, and better understanding of concepts [44]. Online games and gaming offer great potential as a novel and innovative communication strategy to inform the public and citizens [30]. Serious gaming capitalizes on active, personalized, and experiential learning, sur-passing passive instruction [12]. Utilizing gamification, especially via board games, proves to be an effective method for educating individuals about sustainability in a broad sense [27]. Gamification, by making learning more interactive and enjoyable, significantly influences learning, motivation, and outcomes [44].

One of the key strengths of gamification is its ability to educate and inform. By integrating educational content within game apps and providing interactive experiences in gamified environments, citizens are empowered with knowledge about climate policies, environmental challenges, and the consequences of their actions. This accumulation of knowledge serves as a foundation for informed decision-making and fosters sustained engagement with environmental issues. Moreover, through engaging in interactive games and facing challenges, citizens deepen their understanding of how their behaviors impact the environment. This heightened awareness is crucial, as it paves the way for the adoption of more sustainable lifestyles and choices.

5.3 Creating a Sense of Community

Highly socially motivated individuals enjoy meaningful relationships and teamwork, and a team may create a sense of connectedness among players [2]. The domain of digital gaming holds substantial potential as a medium to motivate people's participation in activities that extend beyond mere entertainment [24].

When people believe that their individual actions contribute to protecting the environment, it can create or reinforce a sense of social obligation and responsibility toward environmental protection [2]. Moreover, cities are increasingly adopting urban intelligence by enhancing information systems and utilizing advanced analytics for decision-making and operations [9]. Gamified cooperation represents a way in which individuals assist each other and work collectively to achieve a specific goal within a game [2]. Additionally, games can provide players with the opportunity to discuss any issues raised by the game [30].

Gamification has the powerful ability to cultivate a sense of community and inspire collective action. As residents collaborate to meet game objectives, they become integral to a broader movement toward achieving carbon neutrality in their city. Whether through digital platforms or real-world interactions, gamification unites participants, creating a vibrant community. The cooperative essence of challenges, the dynamic competition

on leaderboards, and the celebration of shared achievements all play a critical role in forging strong communal ties. This cultivated sense of belonging and unity is crucial for maintaining prolonged engagement and driving enduring changes in behavior.

5.4 Lifestyle and Behavioral Change

Changes in technology have been proposed as solutions to our current problems in cities [42]. Gamification helps create an environment in which individuals are intrinsically motivated to engage with material related to the area where behavior change is desirable [27]. It also encourages the public to transition from practices with high carbon emissions to actively participating in low-carbon practices [2]. To foster the expected behavior change, one should appropriately conceive, deploy, and manage gamification [24]. Equally, researchers claim that it is important to consider the potential of modern digital games to engage players in novel, memorable ways that contribute to their understanding, perceptions, and even behaviors [30].

By rewarding positive behavior, gamification can lead to significant changes in individual and collective behaviors. This innovative approach can encourage a wide range of environmentally friendly actions, such as promoting the use of public transportation, reducing energy consumption, and minimizing carbon footprints. Beyond these immediate benefits, gamification has the power to instill long-term lifestyle changes. It can foster a deeper awareness of sustainable living, encouraging people to rethink their daily habits and choices. Moreover, these gamified systems can create a ripple effect, inspiring others within the community to adopt similar behaviors through a combination of competition, collaboration, and the desire to achieve shared environmental goals. Ultimately, gamification not only transforms individual actions but also cultivates a collective movement towards a more sustainable and eco-conscious society.

6 Gamification Strategies for Carbon-Neutral Communities

The collaboration of gamification to foster sustainable communities towards achieving carbon-neutral cities is illustrated in Fig. 2. This model is based on the items identified earlier from scholarly works, and it shows the relationship among them. As seen in the figure, all key elements of sustainable communities are interconnected and must work collectively to achieve the goal. Previous discussions reveal that gamification has four main impacts in the realm of eco-social science, supported by game apps and gamified places. This figure illustrates the flow from game apps and gamified places to sustainable communities, aiming to achieve carbon-neutral cities.

‘Creating a sense of community’ through gamification, derived from ‘building a sense of ownership’ in gamified places, helps achieve two key elements of sustainable communities: ‘community engagement and social participation’, alongside ‘fostering a sense of ownership and responsibility’. Moreover, another gamification item, ‘increasing social participation’, also impacts ‘community engagement and social participation’. This is supported by ‘fostering community engagement’ through gamified places and ‘increasing social participation’ through game apps. Two other key elements of sustainable communities, ‘informed communities and collective commitment’ and ‘eco-social awareness and public education’, are supported by ‘education and awareness’ in

gamification, with contributions from game apps including 'increasing engagement and awareness' and 'scalability'. 'Informed communities and collective commitment' and 'lifestyle shift towards sustainability' are further supported by 'lifestyle and behavioral change' from gamification, with 'influencing public behavior' from gamified places and 'intrinsic motivation' from game apps facilitating these objectives.

Gamified places, featuring three items—'building a sense of ownership', 'influencing public behavior', and 'fostering community engagement'—are categorized in green colors. Game apps, with three items—'increasing engagement and awareness', 'intrinsic motivation', and 'scalable'—are presented in pink color. These two categories are linked to the gamification category, depicted in violet color with four items. As the elements in the gamification category originate from both gamified places and game apps, it is evident that each item from gamified places and game apps contributes to cultivating sustainable communities to achieve carbon-neutral cities.

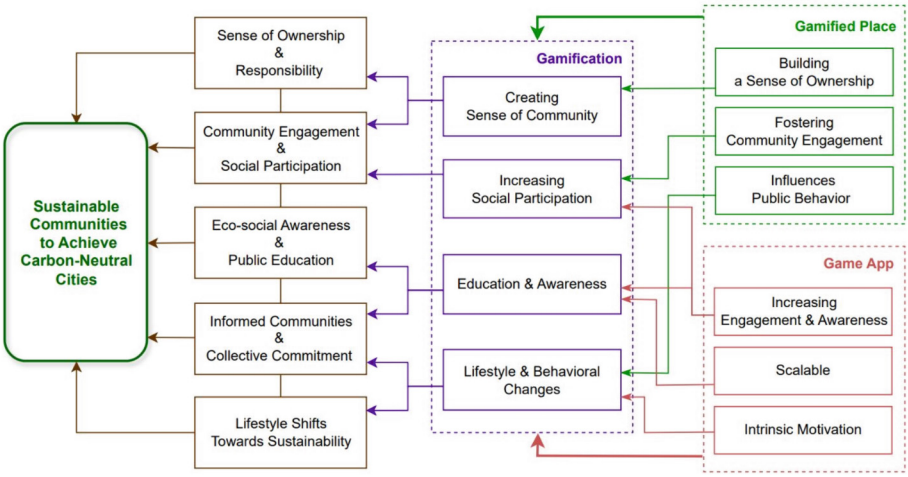

Fig. 2. From Gamification to Carbon-Neutral Cities

7 Choosing the Right Approach-Game App or Gamified Place

In determining whether to adopt a game app or a gamified place to encourage sustainable urban behaviors, one must consider the insights and recommendations outlined in the references. This decision should be informed by an understanding of both the unique and common impacts of these approaches, as well as their respective positive and negative aspects. According to the research reviewed in this article, the positive and negative aspects of game apps and gamified places, as well as their common impacts, are shown in Table 3.

The game app offers scalability and the ability to reach a broad audience through digital means, harnessing intrinsic motivation to increase engagement and awareness. However, their impact tends to be most significant in the short term, with engagement

potentially declining over time. This highlights the need for ongoing innovation and support to sustain interest and promote long-term behavioral change.

On the other hand, a gamified place empowers citizens to actively engage and build a sense of ownership, fostering a sense of community and influencing public behavior toward sustainability. While they present opportunities for meaningful interaction and community engagement, there is also a risk of commodifying everyday life and exacerbating inequality if not carefully designed and implemented.

Both approaches share common impacts in fostering increased social participation, education, and awareness, creating a sense of community, and encouraging lifestyle and behavioral change. These shared benefits underscore the potential of gamification to significantly contribute to the goal of achieving sustainable urban environments.

Table 3. Comparative of Game Apps and Gamified Places to Achieve Carbon-Neutral Cities

Aspect	Impact	References
Game Apps – Positive	Increases engagement and awareness; utilizes intrinsic motivation; scalable	[27, 30, 31]
Game Apps – Negative	Impact most significant in the short term; engagement declines over time; Uncertain efficiency of smartphone tech in environmental monitoring	[32, 40]
Gamified Places – Positive	Building a Sense of Ownership; influences public behavior; and fosters community engagement	[28, 33, 35]
Gamified Places – Negative	Risk of commodification of everyday life; potential reinforcement of inequality	[35, 36]
Common Factors	Fosters increased social participation, education, and awareness; creates a sense of community; encourages lifestyle and behavioral change	[2, 9, 13, 24, 30]

Simplified scenarios used in gaming may not be fully generalizable to real-life decision-making and behaviors [12]. Gamification per se is not necessarily capable of inducing the desired results but needs to be tailored according to the user's preferences [24]. Therefore, regardless of whether a game app or a gamified place is selected, meticulous attention to the design, implementation, and continuous management of the gamification strategy is crucial. This ensures it not only effectively engages users but also promotes sustainable behaviors and supports the overarching objective of achieving carbon-neutral cities. Ultimately, the right approach will depend on a balanced consideration of the advantages and limitations of each option, as well as societal preferences, the legitimacy of the methods, and their acceptance by society.

8 Conclusion

As climate change threats intensify, the urgency to shift towards carbon-neutral cities and sustainable communities has become undeniable. To achieve carbon neutrality, it's essential to comprehend social science deeply, enabling us to navigate the complexities of transitioning societies towards sustainability amidst climate change. Therefore, success relies on a collective effort that integrates advancements in social science with proactive community involvement. In this manner, employing innovative strategies has the potential to actively engage individuals in embracing eco-friendly behaviors.

This paper in Fig. 2 highlights the collaborative role of gamification in nurturing sustainable communities towards achieving carbon-neutral cities. This model intricately depicts the interconnectedness among various elements essential for sustainable communities, emphasizing their collective endeavor towards a common goal. By fostering a sense of community and ownership, gamification effectively contributes to essential components of sustainable communities such as community engagement, social participation, and a shared sense of responsibility. Moreover, boosting social participation and eco-social awareness further bolsters community engagement and fosters informed decision-making and collective commitment towards sustainability. Gamified places, with their focus on building ownership and influencing public behavior, complement the intrinsic motivation and scalability offered by game apps, collectively contributing to the cultivation of sustainable communities and the pursuit of carbon-neutral cities.

When deciding between adopting game apps or gamified places to encourage sustainable urban behaviors, it is crucial to consider the unique impacts and considerations associated with each approach. While game apps offer scalability and engagement, gamified places empower communities and foster a deeper sense of belonging. Despite their differences, both approaches converge in fostering social participation, education, awareness, and lifestyle change, underscoring the potential of gamification in advancing sustainable urban environments. Therefore, the selection of the most suitable approach depends on a nuanced understanding of societal preferences, method legitimacy, and their alignment with the overarching objective of achieving carbon neutrality.

Future research in achieving carbon-neutral cities should focus on the intersection of technology, human behavior, and urban planning. This includes exploring the scalability of gamification strategies, understanding the long-term impacts of behavior change on carbon reduction, and investigating the integration of digital and physical gamification elements within urban environments. Additionally, studies should examine the role of public attitudes and societal values in the adoption and effectiveness of these strategies, as well as the potential for policy and infrastructure to support and amplify the benefits of gamified approaches. By addressing these areas, future research can provide critical insights and innovative solutions to guide cities toward a sustainable, carbon-neutral future.

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Analysis of Seismic Risk and Vulnerability of the Historical Context of Tehran with Emphasis on Resilience Zoning

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Abstract. Historical fabrics are recognized as national capital and tourism destinations worldwide. One of the most important threats to historical fabrics is the risk of natural disasters, especially earthquakes. Over the past two decades, Tehran's historical fabric has come under significant pressure due to rapid socio-economic growth, urbanization, tourism, etc. In this regard, spatial assessment, and zoning of seismic vulnerability in this area are considered fundamental requirements in earthquake impact reduction planning. This study aims to assess the vulnerability of Tehran's historical fabric using the MCDM approach and, in order to clarify the vulnerability status resulting from earthquake hazards and measure the resilience level in Tehran's historical fabric, earthquake risks of the fabric were first identified based on importance, intensity, and probability using the Delphi questionnaire, and weighted criteria by the FAHP method. In the next stage, the ELECTRE method was used to prioritize the resilience level of the four districts of this fabric and rank the potential earthquake risks. The results of the studies, as a resilience zoning map(Result of analysis in ARC GIS), show that more than 78% of Tehran's historical fabric area has been recognized with very high vulnerability which includes the Tehran city center and the central part of District 12. Furthermore, among the identified potential earthquake risks, the risks of increased density of the deteriorated fabric, severe lack or absence of urban open spaces, and high population density are ranked as the highest earthquake risks in this fabric.

Keywords: Vulnerability · Earthquake · Tehran's Historical Fabric · FAHP · ELECTRE · ARC GIS

1 Introduction

It is projected by the United Nations that by 2050, about 80 percent of the world's population would reside in cities. This suggests that a lot of possible calamities will primarily strike in metropolitan areas. After the United Nations International Strategy

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for Disaster Reduction (UNISDR) adopted the Hyogo Framework for Action, the primary focus of disaster risk reduction planning has shifted from merely lowering vulnerability to greatly enhancing and bolstering community resilience. Resilience in this sense is the degree of damage and destruction that a system is capable of withstanding [1, 2]. On the other hand, a crisis is an event that occurs naturally or unexpectedly, imposing problems on human society and disrupting the previously established balance between human needs and available resources. Its resolution requires a series of continuous and dynamic operations and actions known as crisis management [3].The term "earthquake hazard" describes a group of unaffected by human activities natural geophysical circumstances brought about by the shifting, sliding, and displacement of the earth. Given their wide distribution, regularity, and the vast and catastrophic damage they cause, earthquakes—one of the most devastating environmental phenomena—are regarded as one of the most well-known natural catastrophes worldwide [4]. China, Indonesia, Iran, Turkey, and Japan are the five nations most impacted by damaging earthquakes; they account for 16%, 10%, 8%, 4.5%, and 4% of all destructive earthquakes, respectively [5]. Iran is one of the highest-ranking nations in terms of vulnerability to earthquake events and the number of casualties caused by these disasters, as well as ranking first in terms of the frequency of earthquakes with a magnitude greater than 5.5 Richter scale, according to a 2002 report from the United Nations Office for Disaster Risk Reduction (UNISDR). Moreover, Iran is responsible for 6% of global earthquake fatalities and subsequent damages. Remarkably, research by the Ministry of Housing and Urban Development in the National Urban Plan show that half of Iran's urban population lives inin areas with the highest risk of earthquakes. One of the most important factors in reducing earthquake risk is the preparedness of the population to deal with it and increasing urban resilience. One of the best efforts to address the impact of earthquakes, especially in densely populated urban areas, is conducting earthquake risk assessments. Various methods such as seismic data analysis, early warning systems, probabilistic and statistical models, and artificial intelligence have been used to predict earthquake components [4]. However, since humans are involved in the decision-making process, multi-criteria decision-making is accompanied by incompleteness, subjectivity, ambiguity, and other ambiguous qualities. As a solution, numerous studies have combined fuzzy set theory with multi-criteria decision-making methods to reduce these challenges and provide effective and efficient judgments[5]. Regardless, decision-making requires geographical data, which has been a key issue in decision-making since the emergence of multi-criteria decision-making, necessitating the use of geographic information systems [6, 7]. Given the importance of estimating the vulnerability of historical fabrics to earthquake hazards in discussions related to geography and urban planning, this research attempts to provide a suitable estimation of the earthquake vulnerability of Tehran's historical fabrics using ELECTRE FUZZY techniques and Geographic Information System (GIS) by executing spatial and descriptive data and main structural and behavioral elements.

2 Research Method and Case Study

2.1 Research Method

This research has employed a mixed-method approach with practical and developmental objectives to extract results. The overall research process consists of two stages: firstly, data collection, data standardization, weighting using the FAHP method, layer overlay using ArcGIS software, and secondly, prioritization of options using the ELECTRE method. The ELECTRE method is one of the methods available in compensatory models[9]. In this method, all options are evaluated using non-ranking comparisons, and all stages of this process are based on a set of concordant and a set of non-concordant, thus known as a concordance analysis (see Error! Reference source not found.). In this method, options or alternatives are compared in pairs, dominant and inferior options are identified, and inferior or defeated options are eliminated [10].

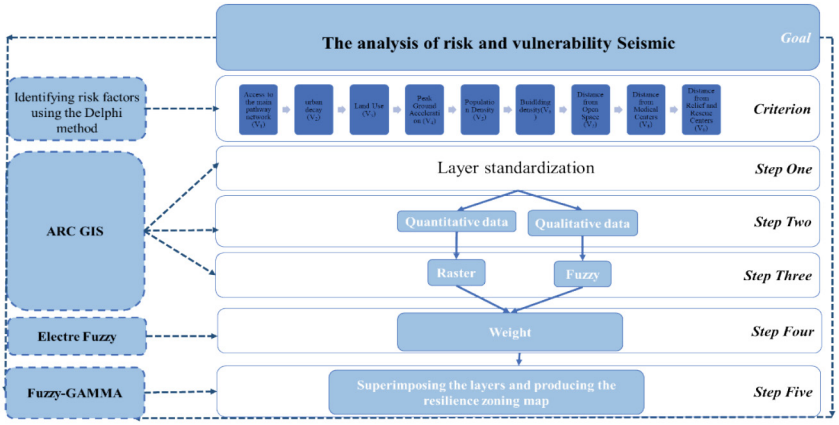

Fig. 1. Research process

2.2 Case Study

The demographic and urbanization landscape of Tehran has undergone significant changes over the past two centuries since its designation as the capital. Presently, the city comprises 22 districts and several associated areas, including cemeteries and southern suburbs [3]. Active faults in Tehran are generally discussed within three main underground zones: northern, central, and southern. The primary zones containing deep faults are capable of generating moderate to severe seismic events in the vicinity and within the metropolitan areas of Tehran and Karaj [11], as well as neighboring settlements [3]. The central and core area of Tehran, including historic neighborhoods such as Emamzade Yahya, Pamenar, Nasir Khusraw, Sangalaj, Bazar, and Sirose (Chaleh Meydan), has been historically and architecturally significant, rich in numerous historical structures, and culturally affluent [12].

3 Discussion and Findings

3.1 First Stage

In the first stage, after data collection, nine research criteria were identified, including access to main road networks, density of deteriorated fabrics, land use, distance from faults, population density, building density, distance from urban open spaces, distance from medical centers, and distance from emergency and rescue centers. Data standardization was performed according to urban regulations and standards, and the criteria were confirmed by experts, as shown in Table 1.

Table 1. Vulnerability ranking assigned for parameters

Ranking	Data type	Fuzzy membership	Consistent	Variables
60–300 m	quantitative	Fuzzy Large	InConsistent	Access to the main pathway network (V_1)
instability -Building quality	qualitative	Fuzzy Large	InConsistent	urban decay (V_2)
Types of land use	qualitative	Fuzzy Small	consistent	Land Use (V_3)
	quantitative	Fuzzy Large	Consistent	Peak Ground Acceleration (V_4)
150–300 m	quantitative	Fuzzy Small	Inconsistent	Population Density (V_5)
Number of floors		Fuzzy Small		Buidlding density(V_6)
1–5 min	qualitative	Fuzzy Small	Consistent	Distance from Open Space (V_7)
1–5 min	qualitative	Fuzzy Small	Consistent	Distance from Medical Centers (V_8)
1–5 min	qualitative	Fuzzy Small	Consistent	Distance from Relief and Rescue Centers (V_9)

After the evaluation criteria were transformed into comparable and standardized scales, the relative weights and importance of each criterion in relation to the research objective were determined using the FAHP method. In addition to Boolean logic and Weighted Overlay tools in ArcGIS 10, two new overlay tools - Fuzzy Membership and Fuzzy Overlay - are available. Overlays using fuzzy logic provide more flexible weighting of evidence and a combination of evidence compared to Boolean or traditional weighted overlays. Furthermore, defining fuzzy numbers and fuzzy scales is necessary for conducting comparisons.

Based on the spatial analysis map (Fig. 2), access to the main road network in the historical fabric of Tehran faces significant challenges due to the predominance of

commercial land use. This area experiences numerous difficulties in terms of access and road network, resulting in slow access and an inadequate network to meet daily needs. Among these challenges, the road network near the Bazar district, due to its commercial nature, increased number of intersections, and narrow roads, has a much worse condition. Considering the high population density in the historical fabric of Tehran during the day, the presence of narrow roads has increased the vulnerability resulting from this parameter to a high to medium level.

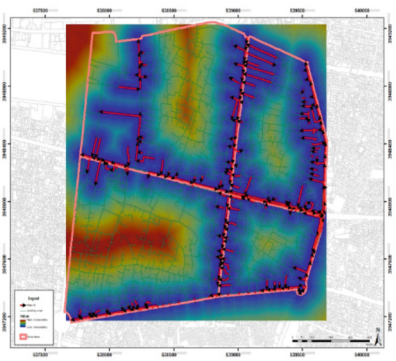

Fig. 2. Analysis of map Access to the main pathway network

Based on the spatial analysis map (Fig. 3), the density of the deteriorated fabric in the historical fabric of Tehran indicates that the vulnerability of deteriorated fabrics and low-quality structures plays a fundamental role in increasing the extent of damage and the spread of crises. Therefore, for this criterion, considering the environmental characteristics of the area, two sub-criteria of instability and granularity have been evaluated. The results of the analysis of the building quality index in this area show that most buildings require repair and are prone to poor quality in the face of earthquakes. Overall, the situation of this parameter falls within the spectrum of high vulnerability, with buildings located in the bazar, Emamzade Yahya, and parts of Siroos neighborhoods having a high density of deteriorated fabric. Meanwhile, the Pamenar neighborhood has a medium vulnerability in terms of building quality.

Based on the spatial analysis map (Fig. 4), the land use in the historical fabric of Tehran indicates that approximately 30% of this fabric is allocated for residential use. A significant portion of these residential areas is located within the deteriorated fabric, which makes this area highly vulnerable due to its resident population. Moreover, the high land value and lucrative nature of commercial uses in this area have led to both legal and illegal changes in land use toward commercial activities. This trend has resulted in most of Tehran's historical fabric being categorized as highly vulnerable in terms of a wide spectrum of vulnerabilities. Based on the spatial analysis map (Fig. 5) of the Peak Ground Acceleration (PGA) in the historical fabric of Tehran, which indicates earthquake hazards, the most threatening faults in this area are the northern and southern Rey faults, the Kahrizak fault, and the northern Tehran fault. These faults show approximately the same level of hazard across the entire area.

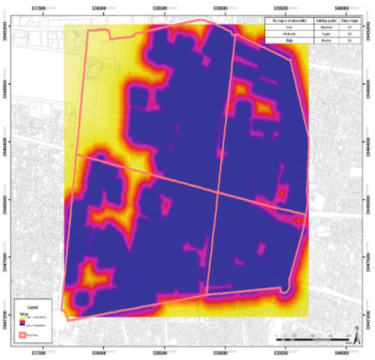

Fig. 3. Analysis of map urban decay

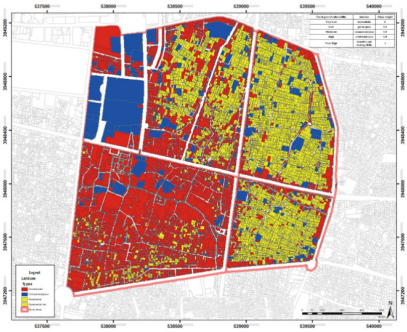

Fig. 4. Analysis of map Land Use

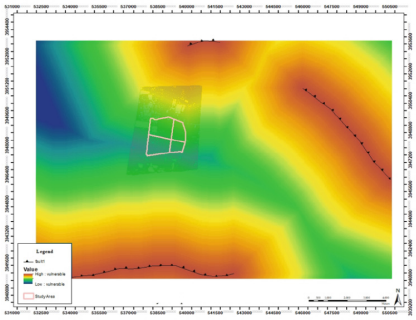

Fig. 5. Analysis of Peak Ground Acceleration

According to the spatial analysis map (Fig. 6) of population density in the historical fabric of Tehran, about 30% of this fabric is designated for residential use, with a significant portion of these areas located within the deteriorated fabric. Due to the high population density in these areas, the human casualties resulting from earthquakes during daytime hours are very high. In this regard, the Bazar neighborhood is highly vulnerable, especially during the late-night hours. Additionally, the high population density in historical areas, coupled with narrow roadways, poses challenges for post-disaster emergency response. Based on the spatial analysis map (Fig. 7) of building density in the historical fabric of Tehran, it is observed that higher-rise buildings increase the risk of road blockages due to building collapse debris, posing challenges for emergency response. Therefore, due to the extensive debris removal required, rescuing residents from multi-story buildings becomes more difficult. Overall, an increase in the number of building floors corresponds to an increase in the vulnerability of buildings to earthquakes. The results indicate that most neighborhoods, including Pamenar, Sirose,

and Emamzade Yahya, have low vulnerability to earthquakes due to their limited building height. However, the Bazar neighborhood is more susceptible to destruction and increased vulnerability due to the presence of multiple high-rise commercial centers.

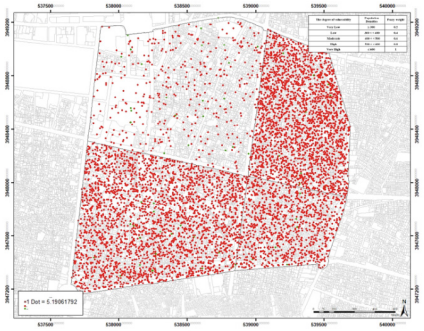

Fig. 6. Analysis of Population Density

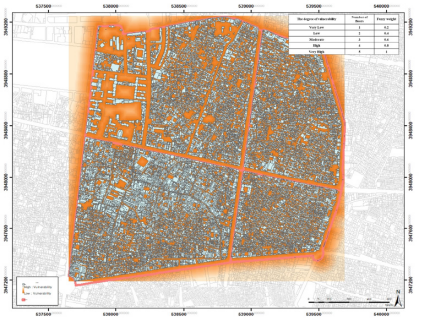

Fig. 7. Analysis of building density

According to the spatial analysis map (Fig. 8) of the distance from public open spaces in the historical fabric of Tehran, the low availability of public open space per capita in this area results in a low to moderate vulnerability of the historical fabric of Tehran in terms of distance from public open spaces. The Bazar and Emamzade Yahya neighborhoods are the most vulnerable residential areas in terms of this parameter. Except for the northern areas with large open spaces, most neighborhoods have very unfavorable conditions in this regard. Based on the spatial analysis map (Fig. 9) of the distance from medical centers in the historical fabric of Tehran, it is evident that this fabric is positioned at varying levels of vulnerability due to the considerable distance from medical centers, ranging from moderate to high vulnerability. Pamenar and the Bazar neighborhoods have the furthest distances from medical centers, resulting in higher vulnerability. Following

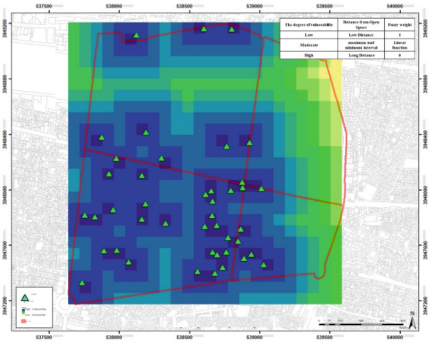

Fig. 8. Analysis of Distance from Open Space

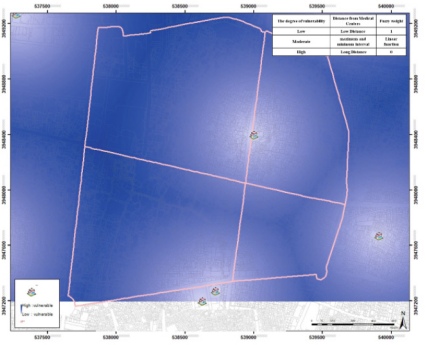

Fig. 9. Analysis of Distance from Medical Centers

these neighborhoods, the Sirose neighborhood is classified as having a moderate level of vulnerability.

According to the spatial analysis map (Fig. 10) of the distance from relief and rescue centers in the historical fabric of Tehran, the distance from these centers plays a crucial role in the speed of response and reducing vulnerability in case of a crisis. The results indicate that all four neighborhoods are classified as having unfavorable to moderate conditions. However, the Bazar neighborhood, due to its sensitivity and the placement of relief and rescue centers, is relatively better positioned in terms of this indicator compared to other neighborhoods.

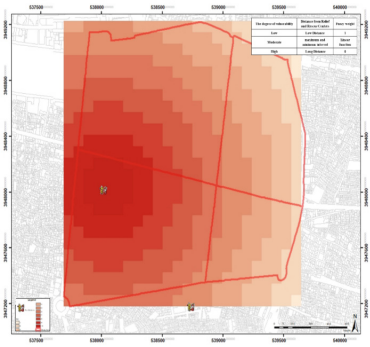

Fig. 10. Analysis of Distance from Relief and Rescue Centers

In this stage of the research, fuzzy gamma (γ) was utilized to estimate the overall vulnerability of Tehran's historical fabric. For this purpose, the data were initially fuzzified. Subsequently, the fuzzy layers were merged together, and a final map was prepared using the Electre fuzzy method to assign weights to the maps, ensuring the impact of each indicator in calculating the actual vulnerability. Maximum and minimum gamma values (0.08, 0.85, 0.9, 0.95) were used to generate the final map using zonal statistics tools for neighborhood fabric calculation [10]. Among these, gamma 0.95 was selected as the best gamma for vulnerability zoning. In the final map (Fig. 11), resilience levels were categorized into three groups based on the intensity of vulnerability: non-resilience, low resilience, and moderate resilience.

3.2 Second Stage

Prioritization of Seismic Risk Using the ELECTRE Method, After overlapping the final layers, four historical and old neighborhoods of Tehran were prioritized in terms of resilience level and seismic risk using the ELECTRE method. Towards the defined objectives, the ELECTRE fuzzy method in this research was conduct-ed in 6 steps using the Electre Solver software: In this study, 4 alternatives (neighborhoods) and 9 criteria were considered, and the manual weighting method along with the use of fuzzy weights from the previous phase was employed for weighting (Tables 2 to 9).

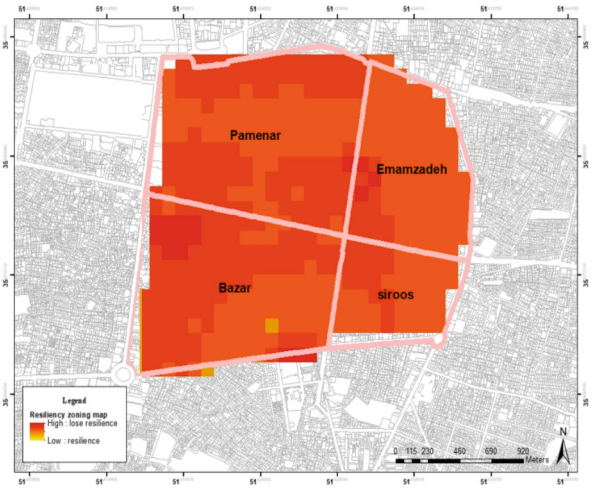

Fig. 11. Resilience zoning map of the historical context of Tehran for an earthquake with 0.95 gamma operator and ELECTRE FUZZY method

Table 2. Decision matrix

Areas	V1	V2	V3	V4	V5	V6	V7	V8	V9
Pamenar	3	4	5	3	3	4	5	1	1
Bazar	5	5	2	3	5	5	3	3	4
Emamzade	4	5	5	3	2	1	2	5	1
Sirose	1	4	2	3	4	3	3	2	2
Weight	0.229	0.192	0.071	0.159	0.026	0.026	0.125	0.008	0.159

Table 3. Descaled decision matrix

Areas	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9
Pamenar	0.213	0.160	0.729	0.560	0.346	0.392	0.656	0.441	0.420
Bazar	0.852	0.480	0.437	0.700	0.577	0.588	0.262	0.55	0.700
Emamzade	0.213	0.800	0.291	0.140	0.577	0.588	0.656	0.55	0.560
Sirose	0.426	0.320	0.437	0.420	0.46	0.392	0.262	0.441	0.140

Dimensionless Scaling of Decision Matrix.

Weighting the Normalized Matrix, In this step, the weights of the criteria obtained in the previous stage are multiplied with the normalized matrix to obtain a weighted matrix.

Table 4. Pairwise comparison matrix of different criteria

Areas	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9
Pamenar	0.048	0.030	0.052	0.089	0.009	0.010	0.082	0.003	0.067
Bazar	0.195	0.092	0.031	0.111	0.015	0.015	0.033	0.004	0.111
Emamzade	0.048	0.154	0.020	0.022	0.015	0.015	0.082	0.004	0.089
Sirose	0.097	0.061	0.031	0.067	0.012	0.010	0.033	0.003	0.022

Table 5. Agreement matrix

Areas	Pamenar	Bazar	Emamzade	Sirose
Pamenar	0.546	0.707	0.192	-
Bazar	0.807	0.928	-	0.807
Emamzade	0.292	-	0.132	0.647
Sirose	-	0.707	0.390	0.488

Table 6. Disagreement matrix

Areas	Pamenar	Bazar	Emamzade	Sirose
Pamenar	1	0.253	1	-
Bazar	0.315	0.071	-	0.420
Emamzade	1	-	1	1
Sirose	-	0.723	1	0.902

Table 7. Formation of the Boolean Concordance Matrix for each of the selected areas

Areas	Pamenar	Bazar	Emamzade	Sirose
Pamenar	0	1	0	-
Bazar	1	1	-	1
Emamzade	0	-	0	1
Sirose	-	1	0	0

Creating a Set of Agreements and Disagreements Contrary to the Criteria, Calculate the Number of dominance and defeat of each of the selected areas.

Table 8. The number of dominance and defeat of each of the selected areas

Result	Number
Bazar	3
Pamenar	1
Sirose	1
Emamzade	0

Table 9. Area of different earthquake vulnerability

Risk potential	Degree of Resilience	Area (square meter)	Area percentage
Very Haigh vulnerability	Loss of Resilience	2692658	78.31%
Haigh vulnerability	Less of Resilience	34384	10%
Moderate vulnerability	Moderate of Resilience	401956	11.69%
Very Low vulnerability	Resilience	-	-
Total area		3438461	100

4 Conclusion

Reducing the vulnerability of Iran's cultural heritage and historical fabric to earthquakes and other natural disasters is one of the country's most significant challenges. In this study, the fuzzy ELECTRE method was utilized to assess the overall vulnerability and resilience of Tehran's historical fabric, integrating it with geographical information systems. The results of the fuzzy ELECTRE calculations indicate that over 78% of Tehran's historical fabric is highly vulnerable, with over 10% at high vulnerability, and over 11% at moderate to low vulnerability to earthquake risk. Additionally, in terms of vulnerability spectra and resilience levels of Tehran's historical neighborhoods, the Bazar neighborhood is classified as highly vulnerable with low resilience, Pamenar and Sirose neighborhoods are categorized as having high vulnerability with low resilience, and the Emamzadeh Yaḥyā neighborhood falls into the moderate to high vulnerability and medium resilience spectrum, prioritizing earthquake vulnerability planning accordingly. Furthermore, among the identified potential earthquake risks, the risk of increased density in the deteriorated fabric, severe lack or shortage of urban open spaces, and high population density ranks highest in earthquake risk for this fabric. Assessing the resilience status of Tehran's historical fabric against potential earthquake crises will play a vital role in crisis management. Due to the existence of a vast area of deteriorated fabric, this area of the city is vulnerable to earthquake hazards. Therefore, determining the vulnerability of the fabric to earthquakes is of utmost importance, both in terms of planning for resilience and emergency management and accommodation.

Disclosure of Interests. The authors have no competing interests. The authors declare that there are no evident financial or personal conflicts of interest that might have affected the results reported in this study.

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Supporting Global Knowledge Concerning Risk Domain: Ontologies Put into Practice

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Abstract. Developing strategies and solutions to cope with the increasing risks that populations constantly face has become essential to encourage effective preventive planning and prompt responses. In this regard, and from a more theoretical perspective, the relevance of developing a formal conceptualization of the world by linking concepts through logical rules to allow knowledge sharing is recognized as the primary purpose by the Authors. Users working in the same Risk domain, intended as a function of Hazard, Vulnerability, Exposure, and Adaptation (as a reducing factor), require a system of explicit representations that can reduce the conceptual and terminological confusion to have a shared interpretation. Therefore, ontologies are employed to overcome such issues. Ontologies can improve semantic interoperability by isolating the core concepts' domain, defining relations among them, and providing hierarchically structured descriptions of the most important concepts and their properties. Thus, an ontology about the Risk domain has been built using the Protégé editor through some steps: identifying the main concepts related to the domain, organizing the concepts through a structured hierarchy that implements the IS_A relation, and finally specifying further possible relations existing among the inserted terms.

Keywords: Ontology design · disaster risk reduction – DRR · multi-risk approach

1 Introduction

Human existence deals with the exposure to multiple hazards. Understanding the hazards and their associated risks may help prevent or reduce adverse consequences. Considering that we live in a multi-risk environment with endless natural and anthropic hazards, many of which cannot be controlled and occur at any time, planning to reduce risk becomes more challenging [1].

A natural phenomenon (such as an earthquake, flood, or landslide) does not represent a disaster alone; nevertheless, it can turn into a disaster whenever it negatively impacts

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vulnerable communities, exposed and/or unprepared for the event. The interaction with the social, political, and economic context makes a natural phenomenon hazardous and produces risks [2]. Indeed, it was recognized the existing link among the concepts of 'risk', 'hazard', and 'society' [3].

Therefore, in a precise period, the complex interaction of dynamic processes that generate hazardous situations and conditions for human life and material goods define the concept of risk [4].

In the scientific literature, it is possible to find a considerable number of elements whose relations with 'risk' are often unclear: they assume different meanings in relation to the context (social, ecological, engineering, and so on). Starting from Blaikie [5], risk is considered a product of natural hazard (shaped by the magnitude and frequency of a physical event) and human vulnerability (result of the interaction of physical and human elements). Moreover, vulnerability can be defined as the interaction between exposure (directly dependent on geographical location, built and natural environment characteristics), resilience (the ability of each element to overcome or adapt to the stressful event), and resistance (the ability of a single individual or group of people to resist the impact from a physical, economic, psychological, and social point of view).

The complex and multidimensional concepts of risk, resilience, and territorial vulnerability can be explained as expressions of the territory as a complex system. During a hazardous event that generates interruption and uncertainty in its components, causing an increase in entropy, the territory can contrast an equal but opposite strength and resilience, increasing its levels of organization. Ecosystems, government, climate, society, and urban environment are all examples of complex and adaptive systems that, when perturbed by a natural or anthropogenic stressor, demonstrate a high capacity to adapt and return to a new state of equilibrium.

The interest and reference to the concept of multi-hazard risk (or multi-risk) was first made in the Agenda 21 Conference in Rio de Janeiro [6] and then in the Johannesburg Plan [7] in which a complete multi-hazard approach was proposed for disaster management and risk reduction.

Since then, many researchers focused on analyzing multiple risks deriving from different hazards and affecting different exposed elements. Hence, many scholars and international government bodies are trying to overcome a critical gap: the lack of precise definitions [8–11].

In particular, the multi-hazard concept is related to assessing different hazards, triggering cascade effects threatening the same exposed elements with or without temporal concurrence [12]. Multi-vulnerability considers different exposed elements with possible different vulnerabilities, changing according to different hazards and over time.

Consequently, the multi-risk concept refers to a complex variety of combinations of risks, various combinations of hazards (e.g., multi-natural hazards, multi-technological hazards, multi-natural and technological hazards combination, etc.) and various combinations of vulnerabilities (e.g., multi-population and buildings, multi-cultural and environmental, complex urban vulnerabilities, etc.) [13, 14]. The multi-risk approach aims at adopting a territorial perspective: a piece of territory is composed of elements at risk that are diversely vulnerable to the various sources of hazards that can affect that area.

Improving a shared understanding and mapping of the increasing risks of extreme and complex disasters is a fundamental pre-condition to understanding the required capability to manage disaster risks and to ensure robust preparedness planning and timely and efficient operational response. Indeed, the Sendai Framework divides its action into four main pillars (priorities) that underline different aims. Among the others, the relevance of supporting risk awareness in all its dimensions (exposure, vulnerability, and hazard) is highlighted, together with the fundamental recognition of the involved stakeholders and their roles in the processes.

Therefore, the paper discusses using ontologies for such purposes to improve the overall knowledge and understanding of the risk concept. An ontology is defined as "an explicit specification of a conceptualization" [15] of which it can explicitly formalize the semantics. Thus, they can work to increase the semantic operability and make the approach to risk definition more systematic.

On the one hand, starting from an abstraction process, the conceptualization step identifies the key concepts that are directly linked to the domain's terms. On the other hand, the specification action makes the meaning related to such concepts extremely clear, proving for them a formal definition that can be automatically decodable.

Therefore, an ontology dealing with the "risk" domain would develop a conceptual model describing the domain's entities and their relations, expressing the entities' attributes and values that such attributes could have. Additionally, it is possible to define rules concerning classes, attributes, and their relations. The success of similar operations is greatly supported by the development of specific automated technologies that can recognize and extract relations existing between concepts. Indeed, the authors choose Protégé as the main tool for building risk ontology. The Protégé editor is a "free, open-source ontology editor and framework for building intelligent systems" [16]. Stanford University developed it in the 1980s; to date, it is used by more than 250,000 people. The tool organizes the knowledge hierarchically by easily entering information that the user can always modify and navigate by interacting with the structured graph representing all the inserted concepts.

The main aim is to build a shared interpretation of the risk domain with its entities so that the various concepts are understandable to both heterogeneous stakeholders and systems, of immediate availability, and characterized by an intrinsic meaning that cannot be misunderstood.

After the introduction chapter, the paper proceeds by deepening the features of the multi-risk approach in connection with the use of ontologies as integrated tools. Therefore, the main features of ontologies linked to the Computer and Information Science field are explained; then, the methodology concerning how the risk ontology has been developed is described by putting in evidence the different designing phases that have employed the Protégé tool. The discussions and the description of future possibilities conclude the contribution.

2 Multi-risk Approach

From the International Decade for Natural Disaster Reduction (IDNDR) in the 1990s, the Hyogo Framework for Disaster Risk Reduction (HFA) 2005–2015 and the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030, science and technology (natural science, engineering to social science) have been recognized as driving forces in the development and implementation of major international disaster risk reduction (DRR) frameworks. Adopting a multi-risk approach is considered a priority in many documents and protocols, especially at the international level and several European research projects aiming at improving multi-risk assessment logic frameworks, methods, and instruments [17].

Despite this, the complex multi-sector dimension of DRR knowledge is quite evident and has not been adequately incorporated into the decision-making process [18]. In particular, among all the stakeholders involved: disaster managers, public administrators, scientists, scholars, NGOs, and experts coming from different disciplines (economics, business management, investment funds and insurance, urban planning, climatology, virology, and civil protection) with different roles and responsibilities in the risk analysis and management process, tend to prioritize different aspects of disasters and find difficulties to collaborate and coordinate during the DDR phases (prevention/mitigation, emergency, response, and restoration) [19].

Even if each typology of risk requires specific and customized efforts and analysis (risk scenario definition), many multidisciplinary principles can support the preventive phase of the DRR cycle: to implement the preparedness and the prevention, it is fundamental to define all the concepts involved (with a trans-disciplinary approach), to map interconnections and dependencies among systems, elements, and actors [20, 21].

Moreover, a multi-risk approach allows an improvement of urban planning and emergency planning with a shared database, information, and rules, significant cost reductions, improvements in the efficiency of risk mitigation and management measures, and better identification of solid actions to perform on the territory (Table 1.). In the case proposed by the authors, the approach also includes the application of risk ontologies. Indeed, integrating ontologies into the multi-risk analysis supports overcoming diverse challenges related to data heterogeneity, diversity of information systems, and complexity of risk interconnections. The latter can be clearly identified and capture the interactions between natural, technological, and socio-economic spheres, thus facilitating communication among stakeholders and enabling a common understanding of the risk domain.

Table 1. Benefits derived by the adoption of a multi-risk approach. Source: adapted from [22].

Strategies/tools	Benefits
Risk assessment and land use planning	– Consideration of cascading effects and interactions between risks and inclusion in risk zoning and land use planning – Comparison and ranking of different risk – Identification of the highest risk in terms of potential impacts – Standardization across risk fields
Emergencies management	– Development of multi-hazards and multi-risks scenarios to manage emergency situations in real-time – Better preparedness due to knowledge of cascading effects
Emergency/Civil Protection Plans	– Identification of the phenomena expected in a territory, thus defining the possible risk scenarios – Better identification of strategies to avoid or reduce possible damage after a hazardous event – Enhancement of population awareness and preparedness facing emergency situations
Risk mitigation	– Better identification of action priorities – Integrated practices – Evidence on increased expected losses due to risk interactions – Cost reductions and improvement in the efficiency of mitigation measures
Institutional capacities	– Improved cooperation and communication between agencies acting at different levels in different risk sectors
Public and private sector partnership	– Enhanced cooperation and communication between the public and private sectors – Need for a new responsibility-sharing mechanism in the case of households exposed to multiple risks (insurance)
Risk Ontologies	– Automatic identification of potential risk scenarios – Provision of a structured and interoperable conceptual framework – Terminology standardization

2.1 The Multi-risk Approach in the Italian Civil Protection Plan

In the Italian context, at the different territorial scales, considering the several tools linked to the study of risk factors in the planning discipline, emergency (or Civil Protection) planning represents a fundamental example of the multi-risk approach to risk analysis in all the DRR phases.

A Civil Protection Plan is constituted by a set of strategies, actions, and operational procedures for intervention to deal with any disaster occurring in a specific territory, but, at the same time, it is also the necessary tool to increase, in ordinary times, awareness of risk (as multi-risk), to organize the available resources and to guarantee the connection among the different administrations and governmental bodies based on a shared strategy. The Civil Protection Plan incorporates the forecast and prevention program. The emergency allows the authorities to prepare and coordinate rescue and response interventions to protect the population and the assets in a territory at risk.

Italian Law 225/1992 enhances the role of the Provinces (a territorial and governmental meso-level between Region and Municipality) in the planning sector, with particular reference to risk prevision and prevention. The Provincial Prediction and Prevention Programs represent the first and essential moment for analyzing and enhancing territory knowledge under the several risk hypotheses. They identify the areas at risk, evaluate the technical characteristics of the existing defense works, categorize the exposed elements, and describe the monitoring activity. They also outline the principal regulations directing to mitigate the effects of the expected hazard, identifying the probability of recurrence, the probable magnitude, the areal extension, the precursors, and the trigger events for each type of risk, and they are also an information tool for the population. These Programs represent the premise of the provincial and municipal emergency plans based on Legislative Decree 112/1998, L.R. 1/2000, and DLgs 1/2018.

At the provincial level, the Civil Protection Plan is a fundamental and necessary tool to face the complex world of civil protection emergencies. It refers to hazardous event scenarios that require the mobilization of the structures and components of the provincial and regional protection and planning system due to the extension and severity of the event scenarios themselves. It is mainly addressed to public administrations and experts. The Province, if a hazardous event occurs, coordinates its interventions with those implemented by the Prefecture:

- Must promptly activate its resources to deal with the emergency (with particular attention to infrastructure system, technological network, and facilities and services network);
- Organizes relief works at the provincial level and activates the urgent services;
- Follows the activation, coordination, and management of provincial volunteering to support the Civil Protection authorities in the territory (Mayor, Prefect).

3 Understanding the Significance of Ontology

The introductive chapter clearly highlights the intention to establish a common way of organizing knowledge regarding the risk domain, to make concepts understandable to an ampler set of stakeholders by establishing a formal and clear intrinsic meaning using ontologies.

The definition of ontology through the history of Western thought assumes different interpretations based on the field of study. Indeed, in one case, it refers to Philosophy, and Aristotle, who dealt with this subject in his Metaphysics, defined Ontology as the science of "being qua being". Therefore, Ontology examines the nature and structure of things regardless of their actual existence. Thus, for example, the Ontology describing unicorns or other fictitious entities is accepted: even if the latter lack evidence, their specific nature and structure can be explained through general categories and relations [23].

In the other case, ontology concerns Computer and Information Science and is identified as "a sort of informative object or computational artifact" [23]. Hence, the existential component is tangible, as Gruber [24] explained: "For AI systems, what 'exists' is that which can be represented."

The previously introduced definition by Gruber in 1993 is the most widely adopted and can be seen as a foundation for computer science tools that are based on ontologies. Indeed, conceptualization is a theoretical model that provides the fundamental concepts linked to a specific domain through an abstraction process; the meanings related to such concepts become unambiguous through a specification that gives them formal definitions that can be automatically decodable and shared between people and software agents [25].

In this regard, the term ontology has a broader meaning than the philosophical one. Indeed, an ontology reflects a formal description of knowledge in terms of concepts, relations between them, properties, and other elements in a specific domain [26]. The tool's conceptual value is well recognized. When applied to complex domains, it enables the capture, explicitation, specification, storage, maintenance, management, and representation of the implicit or explicit knowledge contained in it.

Then, in 1997, Borst specified additional requirements: the conceptualization should be placed at a wider level of shared participation and operated by a machine. He described ontology as a "formal specification of a shared conceptualization" [27]. The following year, Studer et al. [28] affirmed, "An ontology is a formal, explicit specification of a shared conceptualization."

In this way, they merged the previous definitions and elaborated a standard view among those who use this conceptualization and those who are the recipients of the advantages deriving from its adoption; indeed, Studer's meaning considers "a context instead of an individual vision" [23]. In the same year, another definition that emphasizes the role of logic theory as a tool in presenting ontology should be considered. In this sense, Guarino [29] explained, "An ontology is a set of logical axioms designed to account for the intended meaning of a vocabulary."

The number of ontologies available to the public has increased in recent years: some lack good quality, while others have a limited application range [30]. However, this context demonstrates how ontology implementation is no longer a resource for exclusively large projects with significant funding. Some factors contributed, such as the dissemination of the Semantic Web, the arrangement of techniques for engineering ontologies, increased literature about ontologies, access to a large variety of courses and tutorial possibilities, and much more [31]. During the last three decades, ontological studies have significantly developed, implementing theoretical models to more practical implementations directly connected to real-world and large-scale applications. As the

most positive outcome today, the ontological design aims at investing an ampler set of knowledge and different fields of science, such as urban planning, infrastructure, archeology, business, medicine, biology, etc. [32–34].

4 Applying the Ontology Tool to the Risk Domain

The logic scheme adopted to design the risk ontology considers the multi-risk vision. An elevated number of "hazards" and more "vulnerabilities" (objects and subjects are vulnerable in different ways according to the hazard to which they are subjected, and they respond to it in other ways, whether there is contemporaneity or concatenation of events, as well as the units of measure of such vulnerability change) insist on the same territory (being an exposed element) thus generating the study of multi-risk.

Indeed, such systematic vision is employed as a more truthful descriptor of the territory's complex reality to be analyzed and managed (from the point of view of risk reduction in the pre-and post-event, hence of the emergency phase).

Starting from the equation that defines the Risk as a function of Hazard, Vulnerability, Exposure, and Adaptation (as a reducing factor), the ontology has been built following a top-down approach. The latter proceeds by detecting the most general concepts (classes) in a domain, and subsequently, it integrates the structure by specializing it step by step. In this regard, Gandon [35] affirmed, "This approach is prone to the reuse of ontologies and inclusion of high-level philosophical considerations which can be very interesting for coherence maintenance."

Such a method was applied after the first phase, during which the main concepts related to the risk domain were detected by analyzing the existing literature; this action resulted in the drafting of a dedicated glossary that counted 130 terms. Those entities have been evaluated individually without finding common elements and reducing them to a comprehensive explanation. Indeed, a principle of adequatism has been followed, identified as the opposite of the reductionist philosophy, whose goal is to explain complex phenomena by reducing them to simpler and more essential elements.

The next stage consisted of the actual realization of the ontology so that the base knowledge structure could be highlighted once the domain's elements and their relations had been detected. The complex feature of reality, which clearly affects even the risk domain, implies multiple perspectives concerning ontological development [31]. Thus, a single ontology cannot pretend to describe an entire domain fully, and, therefore, the authors adopted a modular approach so that experts in the related scientific discipline can manage each ontology's sections. This is linked to the essential feature of ontologies that, like scientific theories, can be subjected to substantial changes and revisions to support their long-term utility and avoid placing attention on the local utility and the possible short-term effects. Ontologies keep undergoing maintenance, evaluation, update, correction, and adjustment operations to correctly consider further advantages in scientific and personal ontology knowledge.

4.1 The Protégé Tool

As previously mentioned, Protégé has been used to build ontology practically. The platform offers a suite of instruments that facilitate the construction of domain models

and knowledge-based applications with ontologies [36]. It basically provides a graphic and interactive editor for the organization of knowledge. The overall information can be quickly accessed by the users, who can edit it and interact with the ontology directly by browsing the graph and displaying it. The knowledge model used by Protégé offers the advantage of an architecture that guarantees an open and modular tool.

Protégé can interact through a variety of frameworks. In this case, the work has been developed using the desktop system (Protégé 5), which can support many advanced features to enable easy and fast construction and management; the latter is organized by labeled panels that differentiate the program's various functions from the visual point of view.

Using Protégé, the ontology is designed to describe the organizational information scheme. The latter comprises information grouped by classes and subclasses and expressed through a hierarchy. In this regard, the tool effectively implements an entity-relationship diagram, which incorporates relationships only of the type IS_A. Therefore, the main concepts collected in the glossary have been integrated into a taxonomic hierarchy where the nodes represent the classes, and the edges are connected through the IS_A relation. Figure 1 shows the entities' organization through the OWLViz plug-in, which displays only classes linked by this relation, organized by a node-link tree layout [37]. Due to the high number of entities that have been included in the ontology, and visualization quality issues, the picture is showing only a part of the overall design to emphasize how the software organizes the information in a very user-friendly and clear way.

Focusing for example on the hazard component, the most frequently identified disaster risks are addressed in three different categories: natural hazards, man-made hazards, and NaTech. Natural hazards (Fig. 2) are biological, climatological, geophysical, meteorological, extraterrestrial, and hydrological, by which events like epidemics, volcanic eruptions, earthquakes, landslides, and floods affect Earth's surface.

Some of these processes, such as volcanic eruptions and earthquakes, result from internal forces deep within Earth. Other processes are derived from external forces, such as the Sun energy, directly related to hazardous processes such as violent storms, flooding, and coastal erosion. Still, other external processes, such as landslides, result from gravity acting on hillslopes and mountains. The hazardous events have direct and indirect, positive or negative impacts. The term includes economic, human, environmental, and cultural heritage impacts and may include death, injuries, disease, and other adverse effects on human physical, psychological, and social well-being. Man-made and technological disasters, whether caused by natural or man-made hazards, can cause severe damage to individuals, communities, economies, supply chains, and the environment, impact livelihoods, and jeopardize long-term well-being. Man-made hazards (technological and human hazards) are defined as those "induced entirely or predominantly by human activities and choices" [38].

Indeed, the distinction between natural and man-made catastrophes is not always obvious. Most natural and man-made disasters present cross-border risks due to their geographical nature (earthquakes, fires, severe weather, floods, and space weather), as well as the volatility and scale of their impacts (pandemics, livestock epidemics,



Fig. 1. Partial Risk domain entities' organization through the OWLViz plug-in. Source: authors.



Fig. 2. Focus on Natural Hazard classification through the OWLViz plug-in. Source: authors.

nuclear/industrial accidents). Some events are wrongly assumed to be natural catastrophes: landslide at the Vajont Dam (Italy, 1963) as a result of the filling of the basin destabilizing the mountainside; forest fires in Indonesia (2015) as a combination of man and nature (the fires were started deliberately and the arid conditions expanded it); landslide in Shenzhen (China, 2015) where heavy rains had brought down an artificial dump of excavated soil and rubble.

Moreover, a technological accident caused by a natural hazard is known as NaTech, a term initially coined in 1994 by Showalter and Myers. Hazardous industries may be vulnerable to the impacts of natural hazards, so NaTech accidents are a frequent consequence of natural disasters. Under extreme climatic conditions, forest fires impact ecosystems' health and functions. They can cause extensive damage to life and property, as well as the disruption of transport systems and critical infrastructure (airports, power lines, etc.), businesses, and private assets. NaTech events can be potentially disastrous secondary damages caused by earthquakes, releasing hazardous materials and destroying vital transport and technical infrastructure, residential and industrial buildings, and facilities. Cascading effects of flood events may include the loss of vital infrastructure and damage to industrial facilities, causing the release of chemical or radioactive substances. The following Table 2 reports all the entities that have been integrated into the ontology, reporting definitions and examples.

Table 2. Disasters classification. Source: adapted from [38].

	Type of hazard	Definition	Main examples
Natural Hazards	Biological hazard	A hazard caused by the exposure to living organisms and their toxic substances or vector-borne diseases that they may carry	Animal accident; Epidemic; Insect infestation
	Climatological hazard	A hazard caused by long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability	Drought; Glacial Lake outburst; Wildfire
	Geophysical hazard	Also defined as geological hazard; a hazard originating from solid earth	Earthquake; Mass movement (dry); Volcanic activity
	Meteorological hazard	A hazard caused by short-lived, micro- to meso-scale extreme weather and atmospheric conditions that last from minutes to days	Storm; Fog; Extreme temperature

(*continued*)

Table 2. (*continued*)

	Type of hazard	Definition	Main examples
	Extraterrestrial hazard	A hazard caused by asteroids, meteoroids, and comets as they pass near-earth, enter the Earth's atmosphere, and/or strike the Earth, and by changes in interplanetary conditions that effect the Earth's magnetosphere, ionosphere, and thermosphere	Impact; Space weather
	Hydrogeological hazard	A hazard caused to floods and landslides related to soil and land management	Flood; Landslide; Wave action
Man-made hazards	Technological hazards	A Hazard induced entirely or predominantly by human activities and choices. Industrial, transportation and miscellaneous hazards	Chemical-oil spill; Industrial explosion; bridge collapse; rail-road-air accident and so on
	Human hazards	Armed conflicts and other situations of social instability or tension	Civil disorder; Complex disaster-emergencies; Population movements; Cyber security; Terrorist event
NaTech	Mix	Technological accident caused by a natural hazard (Showalter and Myers, 1994)	Vajont Dam (Italy, 1963) Forest fires in Indonesia (2015) Landslide in Shenzhen (China, 2015)

At this point, the central backbone taxonomy of the risk ontology has been put into evidence. However, to capture all the essential scientific information regarding a certain domain, also the relations between and among nodes need to be described. Indeed, additional relations better relate to the ontology's nodes and define the high-level architecture of the risk ontology. The specific relationships have been described via the "Object properties" panel.

Protégé allows the download of a multitude of plug-ins based on the various user's purposes. Figure 3 shows a scheme derived from the *OntoGraf* plug-in; in this case,

the user can only expand a selected relation or all of them simultaneously. However, browsing the ontology proceeds by incremental exploration since the whole expanded ontology cannot be displayed through automatic input; the only way is to click on all classes to expand each of them.

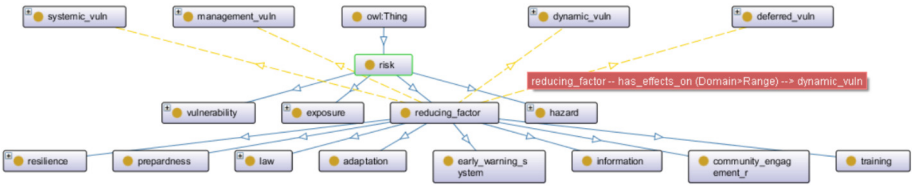

Fig. 3. OntoGraf scheme. Source: authors.

The reported examples demonstrate the benefits deriving from the use of the Protégé tool, serving as a comprehensive digital repository able to detail the relationships between terms, concepts, properties, and logical rules within a specific domain. Indeed, it provides support for graphical representations helping the users to identify information quickly and intuitively. Moreover, graphical representations help to understand the structure, observe the changes, and analyze the relationships between the various resources.

5 Discussion and Conclusions

Understanding the complex interaction between dynamic processes, societal factors, and physical hazards, which defines the concept of risk, is crucial for effective risk reduction and disaster management. Particularly, the multi-risk approach underscores the need for precise definitions and frameworks to analyze multi-risk environments effectively. Indeed, employing systematic frameworks like ontologies let the different stakeholders involved better identify, assess, and mitigate risks, ultimately enhancing resilience and reducing the adverse impacts of disasters. The improved understanding is ensured by a consistent level of semantic interoperability operating across different information systems and databases.

The Protégé tool provided a comprehensive organizational information scheme concerning the risk domain and captured the interactions between its components. It offered an intuitive and easy graphical representation and opportunities for further developments. The proposed application supports the possible integration of ontologies into decision support systems for disaster management and emergency response to changing environmental conditions and socio-economic factors. Therefore, ontological knowledge can be exploited to provide real-time recommendations, predictive models, and risk mitigation and management strategies.

Moreover, the level of cross-disciplinary collaboration is enhanced and subjected to improvements, bridging the gap existing between different disciplines and enabling experts to share knowledge and resources thanks to standard representations of risk-related concepts and relationships.

Overall, the proposed ontology aims to clarify definitions and relationships among elements that would otherwise remain unorganized, thus contributing to a better understanding and management of risks. Applying ontologies in urban and territorial planning could entail adopting an inter-scale approach that engages various institutional levels to ensure the compatibility and coherence of their planning tools. In such a scenario, enhancing the interoperability of geographic databases becomes crucial for promoting transparency and objectivity in institutional decision-making processes.

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Architectural Design Strategies and Tactics as Driver of Critical Awareness: A Research by Design Application for Vulnerable Communities in Ciudad Juárez

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Abstract. This paper is the outcome of a joint-research-project initiative settled between the Tecnológico de Monterrey Campus Chihuahua (Mexico) and the University of Pavia (Italy) within the international research framework under the title Vulnerable Socio-Ecotones research project. The study focuses on the region along the US-Mexico central border, where socioenvironmental issues are extremely complicated and getting worse due to the current political, health, and environmental crises. The research has been implement using onsite participant observation, a detailed literature review on architecture and urban studies of Juárez's urban. The outcome of the study is a series of design reports realized through the architect's means of expression (plans, drawings, perspectives, collages, etc.) revealing possibilities of architecture against the actual conformity of design practices imposed by the actual patterns of urban space development. Our design proposals go beyond both theoretical research and pedagogical research creating a new understanding and hope that to change the vulnerable situation is possible through an active rejection of ongoing and imposed urban processes.

Keywords: Architectural Design · Urban Vulnerabilities · Vulnerable Communities · Counterdesign · Research by Design · Design for Vulnerables · Architecture and Urban Spatial Structure

1 Introduction

This paper is the outcome of a joint-research-project initiative settled between the Tecnológico de Monterrey Campus Chihuahua (Mexico) and the University of Pavia (Italy) within the international research framework under the title Vulnerable Socio-Ecotones research project [1].

The research project Vulnerable Socio-Ecotones seeks to explore territorial phenomena associated with the dimensions of social and environmental fragility, emphasizing the interrelationships between these two dimensions and their consequences for the practice of urban and architectural design. The study focuses on the region along the

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US-Mexico central border, where socioenvironmental issues are extremely complicated and getting worse due to the current political, health, and environmental crises. Given the obvious interdependence of social and environmental issues, it is critical to comprehend the urban dynamics in this complex context impacted by major crises. A context such as the Ciudad Juárez - El Paso metropolitan area is of great interest, which presents concerning social and environmental risks. An already challenging situation has been made considerably worse by the current problems, which have led to a sharp rise in the disparities between the two states, regions, cities, and social groups [1].

The research goal of the paper is to create an understanding and hope that to change the vulnerable situation is possible through an active rejection of ongoing and imposed urban processes by the means of architecture. To achieve this goal, we apply the research by design approach on specific urban areas of Ciudad Juarez, namely the Zone 2 in the eastern side of the city. In detail this study examines how architectural design may act at the urban level contributing to a change of perception of the urban space and effects on the construction of Ciudad Juárez's urban structure.

The article is structured in five sections. After this first section as introduction the second one is about the description of the research framework, methods and analysis needed to understand the spatial structure of the city and neighborhoods of Ciudad Juárez. The third section introduces in detail the research domain and context including the historical background and current status in terms of urban and architectural morphology. This section brings us to recognize five concepts useful to set a broad-spectrum of patterns that will be taken in our design actions as described at the section four. The fourth section is the most important one, and it includes both analysis and projects visualization on what principles of innovation can be promoted for reducing vulnerability in urban communities in Ciudad Juárez. Finally, the project outcomes are critically discussed in the fifth section which also includes recommendations for future research and comparisons with similar projects.

2 Research Framework: Method and Research by Design Approach

This paper is built on the groundwork laid in previous research by the authors [2–8] on the topic of vulnerable communities. Our method is distinguished by onsite surveys, desk research and experiment through research by design approach. The outcomes of which is both written texts and architectural design works and pilot project.

The research framework can be summarized in two main work packages and related tasks that involves strategies in a sequence of distinct phases.

First work package and related tasks:

- Knowledge preparation: definition of the application domain.
- Data collection and definition of the goals and strategies (taken from a wide range of scientific literature, documents and materials).
- Creation of a design strategies.

Second work package and related tasks:

- Application of the strategies in selected contexts of Ciudad Juárez specifying the main aims to achieve in those specific urban areas.
- Envisioning architectural development in three selected areas through meta-projects designed based on the tactics deduced from the strategies. The three meta-projects show the validity of the whole approach.
- Revision and adaptation of the results of the strategies.

The research has been implemented using onsite participant observation from a larger study that was conducted in Ciudad Juárez in 2021 and 2022. In addition, offline research and a review of previous morphological and empirical studies on the history of Juárez's urban evolution have been conducted along with literature review on the city's local planning and architecture history, and the changes involved in significant urban policies and plans; official documents and reports on significant urban plans and development projects have been used; including data analysis was made from government statistics and the Sistema de Información Geográfica Municipal (SIGMUN).

Moreover, the research by design approach was developed from previous experience developed by the authors [9–12].The research by design approach is a type of academic investigation through which design is explored as a method of inquiry, by the development of a project and also exploring the different materials by which a design is carried out. It has been widely described, defined and validated by many scholars worldwide such as for example Hauberg [13], Roggema [14], Frieling [15], De Jong [16], Nassauer and Opdam [17] and Creswell [18].

3 Research Domain, Context Description, Historical Background and Current Status

The geographic area of Ciudad Juárez - El Paso is the second largest transborder agglomeration along the Mexico - U.S. border. Ciudad Juarez is a municipality in the Mexican state of Chihuahua and El Paso is a city in and the county seat of El Paso County, Texas, United States. A bloody war between cartels in the years 2007–2011 is among the main causes of important socio-environmental conflicts in the city. Although violence has declined sharply in recent years, these socio-environmental conflicts, aggravated by the current social, political, environmental and health crisis, continue to afflict the population of Ciudad Juárez.

This urban agglomeration shows alarming levels of vulnerabilities which have been increasing more and more in the last decades and are projecting dark shadows on the sustainable future of the Mexican city [19]. Thus, the first challenge which we had to face was how to describe the complexity of the urban morphology background of Ciudad Juárez and the current status of its architecture. Our findings bring us to recognize five concepts useful to set a broad-spectrum of patterns that could be taken in account (or exclude eventually) in our design actions.

3.1 The Architecture and Urban Spatial Structure of a Borderland

Martén and Boano conceptualize the notion of "checkpoint urbanism" as the main strategy that has been used (consciously or unconsciously) to design the image of Ciudad

Juarez, and it has had a transformative spatial role when considered across the dimensions of infrastructure and stigma, triggering a material/symbolic tension. By this urbanism, "*the checkpoint surroundings acquire a magnetic significance, due to the resulting transit dynamics and the surveillance deterrents at the core of their function. Furthermore, their dual nature – official and criminal – has branded the region as a criminal outpost, stigmatizing the people inhabiting it, and perpetuating the idea that Juarez is defined by its violent infrastructures*" [20]. The case of Ciudad Juárez explains how economic and capital interests, spatial codifications of control, a weakened state apparatus endangered by violence, and a mix of these factors are consequence of the unique characteristics of the borderland and explain Juarez's urban evolution. Thus, by the urban evolution studied through the lens of the concept of checkpoint urbanism, what we can take for our design is that the historical characteristics of Ciudad Juárez - violence, production, and mobility - have had a dual territorial impact: the city's urban space has been shaped by cross-border dynamics, and the city's identity has been shaped by the formation of a character construct that stigmatizes the city as a symbol of extreme violence.

On the same line of study Gamlin in her article has theorized that "*urban gender violence – including gang violence and public violence against women – as a consequence not of poverty or urban marginality, but of its location and function within a globalized world, demonstrating how globalization, as a suspension of the nation state, repurposes historical and gender divisions to serve the global economy*" [21].

Moreover, Gamlin has argued that coloniality as expression of globalization as an axis of inequality structures and constricts Juarez City's development, including its urban morphology development. Being the urbanization of Juarez defined by its coloniality, Gamlin suggested that the urban distortions that result from a local economy focused on production for an international consumer global market create frictions that have pushed gender inequality out of the household and into the public realm, therefore changing urban spaces. According to this insight, what we can take for our project design, is that we cannot reconfigure how we theorize urban spaces, but we can use design as a critical means from which to rethink the awkward urban results of globalization and the coloniality development [21].

3.2 A New Urban Centrality

César M. Fuentes, in his seminal essay on Ciudad Juárez urban morphology, examines the changes in urban function and its effects on the construction of its urban structure. Fuentes point out that "*The changes in Ciudad Juárez's urban function have transformed its internal structure. Its shape has been influenced by the interaction between the local economy, social agents, and the territorial expression of transborder and transnational processes. These processes have made the construction of the border urban space quite unique. The most significant changes to affect Ciudad Juárez's urban function were its establishment as a border port and its incorporation into the global production market as multinational companies invested heavily in it. The city's new function as a port of entry generates two processes. The first involves the establishment of social and economic ties with communities in the southwestern United States, resulting in the city's new role as a regional service center. The second, stemming from its proximity to the border, involves high demographic growth rates that result from the northward pull*

by a large number of persons who seek better living conditions in the United States. The effects of these processes on urban structure can be seen in the presence of a tourism district within the central business district near the port of entry. High-income residential areas were concentrated in the central part of the settlement, while middle-income areas occupied an intermediate position between the central business district and the peripheral lower-income housing [22].

Within this context, the current urban structure is characterized by centrifugal forces (economical, political, social, environmental forces) that eject from the city life the most low-income and vulnerable populations. If this affirmation might sound trivial, we think that it is of vital importance instead to consider in our design the transition of the city's urban structure to a multicentric organization. In recognition of multicentricity city's organization architectural design can offer solutions to bring the marginalized urban space in a new perspective of centrality in both physical and urban space identity [22].

3.3 The Identity of Transitional Architecture

Sáinz and Banister in their study "*Transitional Architecture or Espacios de Paso y Simulacro*" [23] attempted to address the general questions on how architecture and urbanism have reciprocal cultural influence on the physical-spatial elements that figure prominently the borderlands imagery. Their answer was that this ephemeral and relative nature of Ciudad Juarez space is what shapes its peculiar architectural features. It is that to say, architecture becomes transitional by the fact of being located in borderlands between one cultural space and another, spaces that refer to a distinct national juridical sphere.

"*Transitional architecture*" is, actually, a contradiction in terms in which the natural feature of permanence of architecture blur into the domain of the ephemeral things. The transitional feature of architecture is characterized by provisional architectural elements, space and activities that, in order to be effective, disconnect relationship between people and place through a more generic use that removes cultural specificities and is devoid of the capacity to provide a sense of identity or affirmation as a place. Transitions tend to induce the non-place, the meaningless [23].

To use Sáinz and Banister's words, the Transitory architecture is: "*a) diverse, because regional ethnic group coexist in national spheres with their own forms of representation; b) deterritorialized (delocalized) because at one and the same time it expresses various times and cultures; c) a mosaic of superimpositions in three primary senses: of both nationalities, of multiple regionalities, and the ephemeral with involuntary permanence; d) a form of resistance, as identity is a tool of survival; e) ephemeral because it does not depend on permanence; and f) a gesture of belonging in the face of uncertain- ty. It offers a position to the resident in relation to everyone else. Architectural prototypes are fillers that condense either one's own or alien images*" [23].

3.4 The Values of Informal Urbanism and Architecture

The informal settlements are not subject to planned or regulated municipal systems and do not adhere to any disciplinary architecture or urban design frameworks. Nevertheless,

this does not negate the possibility to apply a series of design techniques that may create opportunity to reduce social and environmental vulnerability of these urban areas [24].

Regarding the informal urbanization many authors and scholars, such as for example Roy [25, 26] or Gamlin [21], refer to informality as a method of organizing life in marginalized suburbs that is not an unregulated process, 'but structured through various forms of extra-legal, social and discursive regulation… Producing an uneven geography of spatial value' [25].

The spontaneous urban growth of these cities demonstrates a remarkable degree of planning flexibility and pragmatism. The grid that was first put in place still meets the needs of this community quite well, indicating a cultural or intuitive awareness of the size, dimensions, and relationship between a street and a block. Residents have created discrete neighborhood districts inside this block arrangement, which frequently represent social clans from their original campo communities. A functional open space, schools, marketplaces, and churches have all been incorporated into the urban fabric of those informal districts. The people of Juarez have started to successfully negotiate the provision of infrastructure, urban services, and clear land titles through popular grassroots mobilization [24].

Jose Castillo, in his study of the evolution of *colonias* in Mexico City, calls this informal urbanism and architecture, a highly sophisticated developmental process which leads to a level of social interaction, plurality, and spatial complexity to which other planned communities can only aspire [27].

Using Neza in Mexico City as a case study, Castillo pointed out that *"After 1973 Neza began implementing formal planning procedures. The State's efforts focused on granting clear and legal land deeds and organizing urban services. A parallel history architecture and planning decisions continued to be made by individuals and organized groups, resulting in the progressive construction of the individual private dwelling, as well as the construction and appropriation of public space"* [27]. Yet, Castillo stated: *"The architecture and urban space in Neza have no fixed image: they are constantly evolving. In a few short months, a back-of-the-lot shack built with makeshift materials and rough exteriors may evolve into a 'smooth' bunker of concrete block. A prevailing issue is nevertheless the way in which decoration is applied freely to overcome the standard or generic quality of the structure"* [27]. This description could be similarly used for Ciudad Juarez *colonias* and districts.

On the other hand, the study by María Arquero de Alarcón and McLain Clutter of the Taubman College, University of Michigan, focusing on Chimalhuacán district in Mexico City, point out a similar result but highlighting a different issue occurring in many *colonias* in Mexico: "*this ostensibly informal development is in fact carefully planned and executed as a means of social, political, and spatial control of disenfranchised populations by politically motivated "social organizations." In the absence of effective governmental policies to provide housing for the expanding population of the urban poor, these organizations seize unoccupied land, often in disregard of existing ownership, environmental or regulatory structures"* [28].

3.5 The Re-Appropriation of the Public/collective Space

Ximena Arreola [19] along with a team of Tecnologico de Monterrey have had conducted and important study on the needs for urban-architectural interventions highlighted by civil association active in vulnerable communities of Ciudad Juárez. Two different conditions were studied and compared: (1) urban-architectural interventions that civil associations are actually promoting and (2) desires that civil associations would make to builders and designers in the hypothetical condition of be able to count with high economic resources. The results showed that the most requested interventions are those that allow individuals to appropriate public spaces to create a sense of belonging to the local community to which they belong. Further it emerges that the gap between implemented interventions and desired interventions remains wide, showing a structural powerlessness of the associations to be able to effectively affect reality as they could potentially do [19].

4 Design Phase and Project Visualization

The design phase forms the heart of the research by design process, and it has been framed according to previous experience developed by authors [9–12]. A transdisciplinary and international design team, composed by senior researchers, PhD students, practitioners and experts from both Tecnologico de Monterrey, Mexico and University of Pavia, Italy, engaged in an international collaboration between the two institutions. The design phase began with a series of field trip to Ciudad Juárez during the academic year 2021–2022 and was organized for team design members to observe the dramatic urban phenomenon underway at various scales in the environment in and around the city. During the field trip, the design team made analyses and collected data on the context and, most important, conducted unstructured and structured interviews with citizens and members of the civil associations. Design team members also attended seminars (online and offline) and exchanged ideas about vulnerable communities and sustainable development. All the information collected along with desk research and the literature review provided the basis for the site evaluation, analysis of existing conditions and, mainly, the mapping of the urban landscape patterns. Following the field trip, design team activities were structured around groups to systematize the fieldwork materials. Based on these findings, the researchers were able to make preliminary decisions about features, and then to define the on innovative “collaborative design” between members of both institutions in order to develop, collectively, intervention proposals (urban or architectural) for the most socio-environmentally vulnerable areas in Ciudad Juárez Zone 2.

The outcome of the design phase was a huge number of sketches, plans, drawings, perspectives, collages, videos etc. collected in twelves design reports of which three of them are shortly introduced in the next section.

4.1 Three Selected Projects for Three Design Strategies

It is impossible to fully include in this conference paper the huge amount of material produced. For this reason, this section introduces three selected projects which summarize the whole design package through a miscellany of the most significant images

which are relevant to represent the entire architectural narrative. As first, three types of information have distinguished our process with the aim to outline the full context of the selected site project: (1) a data collection tactics through observations, (2) documents review and (3) visual information has been implemented [18]. In addition, a distinction between interactive data or non-interactive data engagement has been specified.

The design team members constantly exchanged their understanding and new knowledge during the design process. New research inquires emerged during the team discussion on the design options, and the architectural design has been modified consequentially and then used to evaluate the research conclusions. In so doing, a circular iterative process has been applied. The following Figures (from Figs. 1 to 14), provide the visual representation of the architectural design products and offer a summary of the ultimate outcomes of this 'exchanging knowledge and understanding' iterative process.

In conclusion of this process, three design strategies have been defined as follows:

1. Break the wall, the enclosure/fence. Open the fence/wall. Visibility and openness of public facilities/collective buildings.
2. The non-wall. The wall as a space. The wall as a living place: the dichotomy of the wall, from the wall as a spatial dispositive of separation to the wall as a spatial filter, place of connections, place of communication.
3. The public for the collective. The occupancy of the public space. Urban occupancy through the public facilities.

Through the visual description of the design outcomes from Figs. 1 to 14, it is possible to confirm that the proposed architectural design strategies and tactics have the potential to become a catalyst for critical awareness among the citizens of Ciudad Juárez Zone 2. These projects may also be viewed as result of, and new possible starting point for policymakers, citizens, stakeholders, and designers, providing them with a list of priorities that could help to alleviate the actual vulnerable condition.

The architectural projects are presented in summary at three design scales as follow:

– Analysis at the scale of whole city with focus on the Zone 2;
– Conceptualization of the design at the urban design scale with the aim to propose how to make physical changes to reduce vulnerability;
– Sketches of the architectural design building solution to study a single plot building regeneration design. The scenarios have been visualized also through 3D models including physical models and 3D virtual models.

Project 1 - break the wall, the enclosure/fence. Open the fence/wall. Visibility and openness of public facilities/collective buildings.

Project 2 – the non-wall. The wall as a space. The wall as a living place: the dichotomy of the wall, from the wall as a spatial dispositive of separation to the wall as a spatial filter, place of connections, place of communication.

Project 3 - The public for the collective. The occupancy of the public space. Urban occupancy through the public facilities.

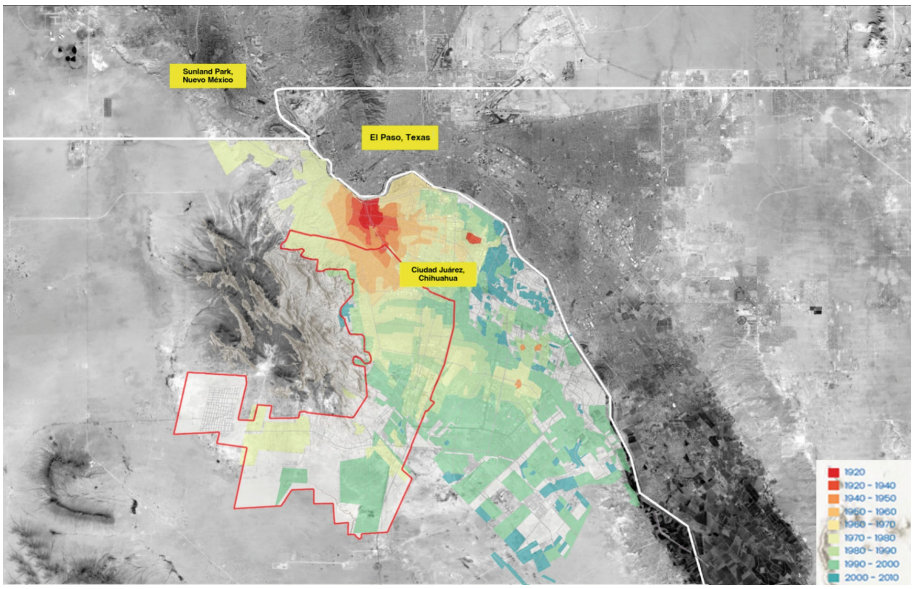

Fig. 1. Satellite image and historical phases of Ciudad Juárez. Highlighted with red line is the Zone 2. Source: Adapted from Mapa 4. Diagrama de crecimiento histórico de Ciudad Juárez, ONU-Habitat con información de IMIP 2022, e INEGI 2020.2040 and Diana Torres, TEC.

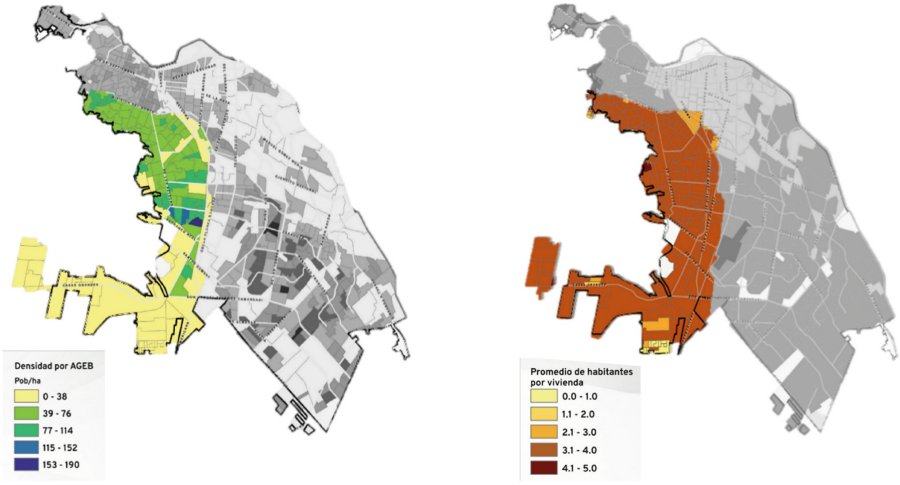

Fig. 2. Population Density per AGEB in Cd. Juárez Zone 2 2020 (left) and average number of inhabitants per home per AGEB, Cd. Juárez Zone 2, 2020 (right). Source: Adapted from https://www.imip.org [29–31] by Diana Torres, TEC.

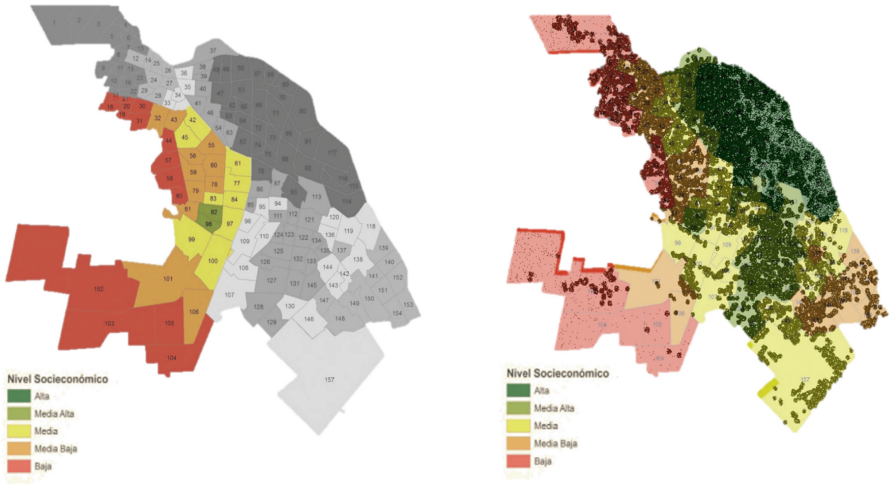

Fig. 3. Socioeconomic Levels per AGEB, Cd. Juárez, Zone 2 2020 (left) and area of Criminal Incidence, Cd Juárez Zone 2, 2020 (right). Source: Adapted from https://www.imip.org [29–31] and by Diana Torres, TEC.

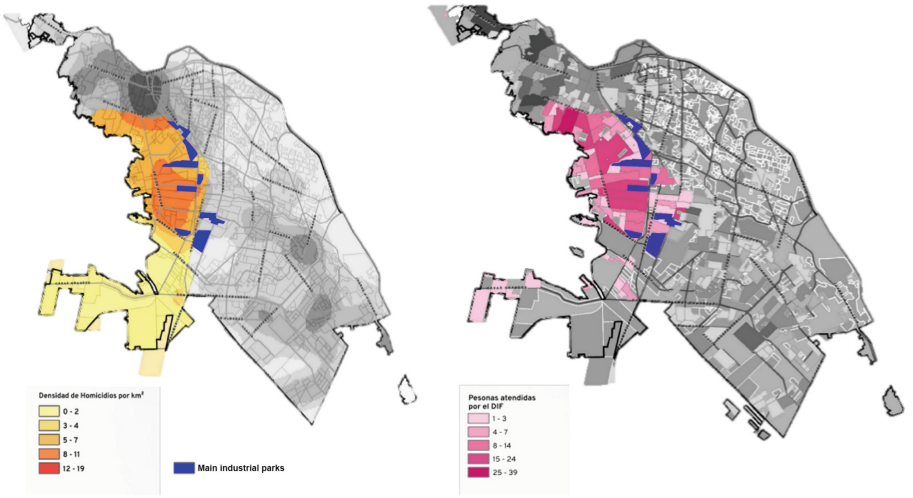

Fig. 4. Spatial behavior of homicides, density for sqkm, Cd. Juárez, 2020 (left) and People served by the *Sistema Nacional para el Desarrollo Integral de la Familia S*DIF per AGEB, Cd Juárez Zone 2, 2020 (right). Source: Adapted from https://www.imip.org [29–31] and by Diana Torres, TEC.

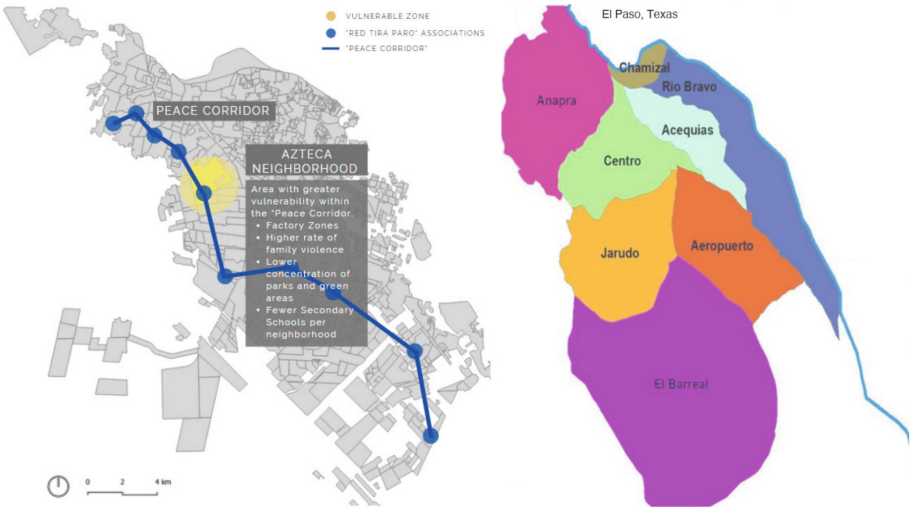

Fig. 5. Track of the project called "Corredor por la paz" ("Peace Corridor"), which is funded by Ficosec Júarez. This corridor forms an intervention belt with young people in vulnerable situations throughout Ciudad Juárez in 68 neighborhoods, in which more than 9 thousand young people benefit with different cultural, sports, training, educational and accompaniment activities (left). Ciudad Júarez districts denomination. The Zone 2 under investigation and the "Corredor por la paz" include all the most vulnerable areas of Ciudad Júarez (right). Source: Diana Torres and Karol Serrato, TEC.



Fig. 6. The three selected site project are located along the "Corredor por la paz" ("Peace Corridor" within the most vulnerable areas of Ciudad Juárez. Those urban areas are characterized by typical informal settlements. Source: Adapted by Authors from Diana Torres, Karol Serrato and Daniela Luján TEC.



Fig. 7. Aerial view and photos survey of the three selected site project. 1- leftover space; 2 – triangular space closed by walls; 3 - empty public space surrounded by roads Adapted by Authors from Greta Cozzi and Martina Rinaldi, Clizia Caroli and Enada Cela, Giulia Venanti and Ilario Piscioneri UNIPV.

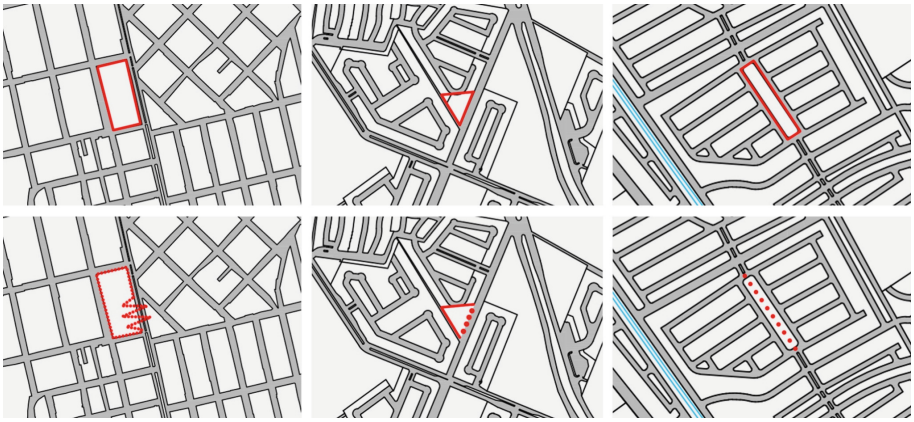

Fig. 8. Concept design. 1- breaking the wall; 2 – the wall as a living place; 3 - the occupancy of the public space. Source: Authors

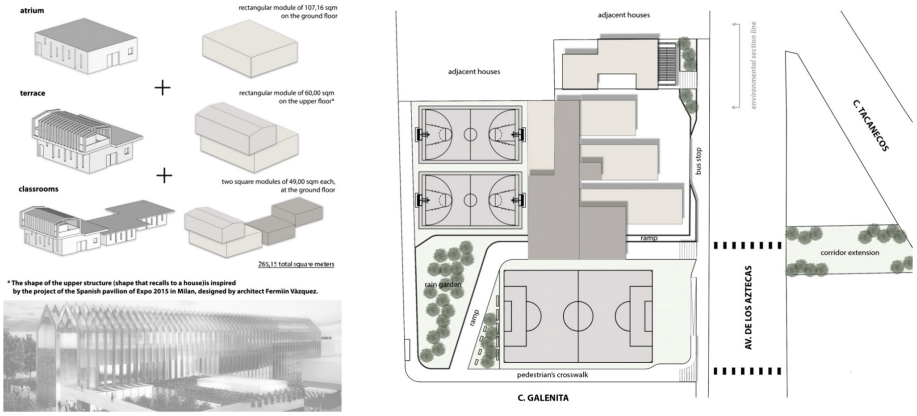

Fig. 9. Conceptual design Project 1- breaking the wall. Source: Adapted by Authors from drawings by Greta Cozzi and Martina Rinaldi, UNIPV.

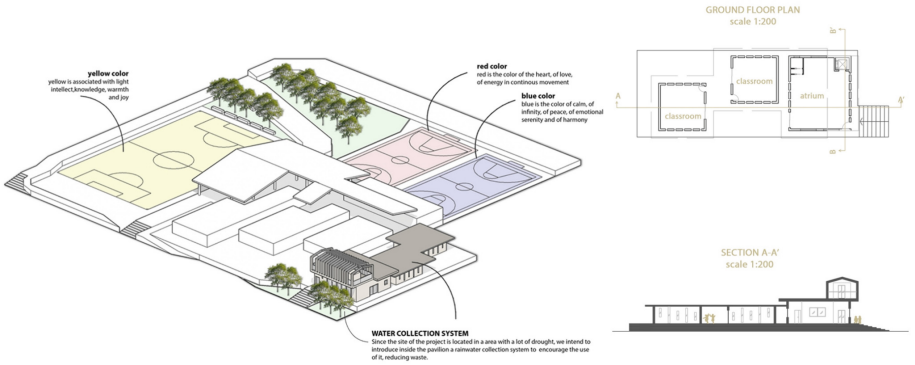

Fig. 10. Conceptual design Project 1- breaking the wall. Source: Adapted by Authors from drawings by Greta Cozzi and Martina Rinaldi, UNIPV

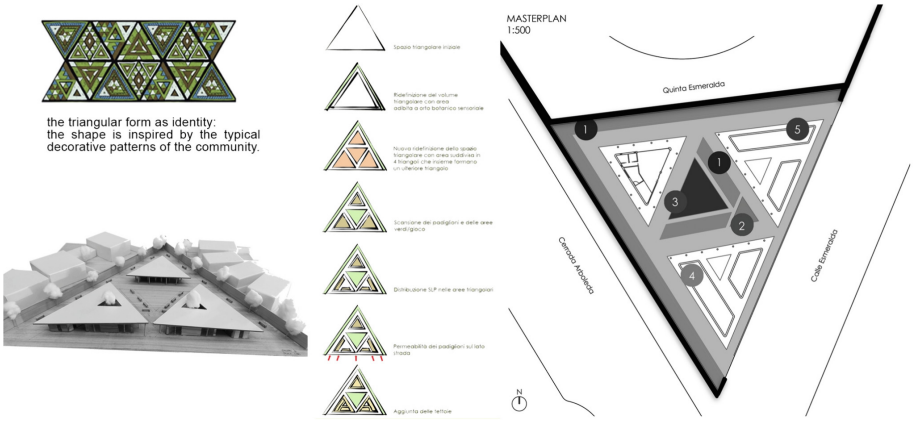

Fig. 11. Conceptual design Project 2 - The wall as a living place. Source: Adapted by Authors from drawings by Clizia Caroli and Enada Cela, UNIPV

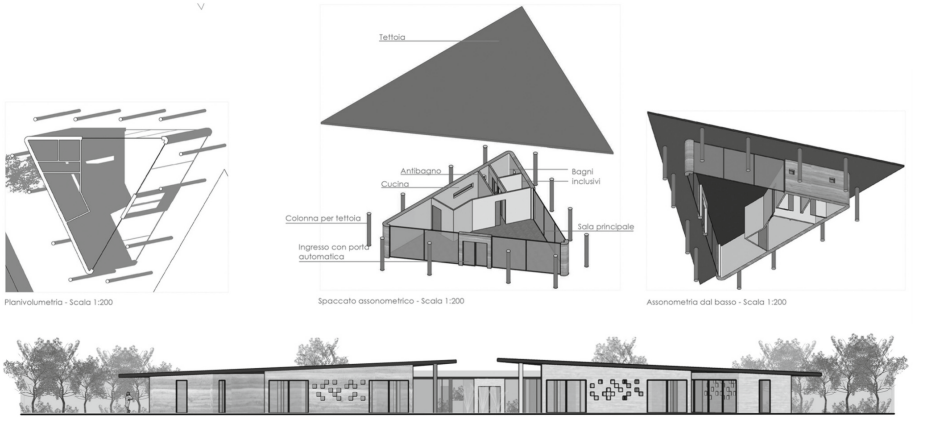

Fig. 12. Conceptual design Project 2 - The wall as a living place. Adapted by Authors from drawings by Clizia Caroli and Enada Cela, UNIPV.

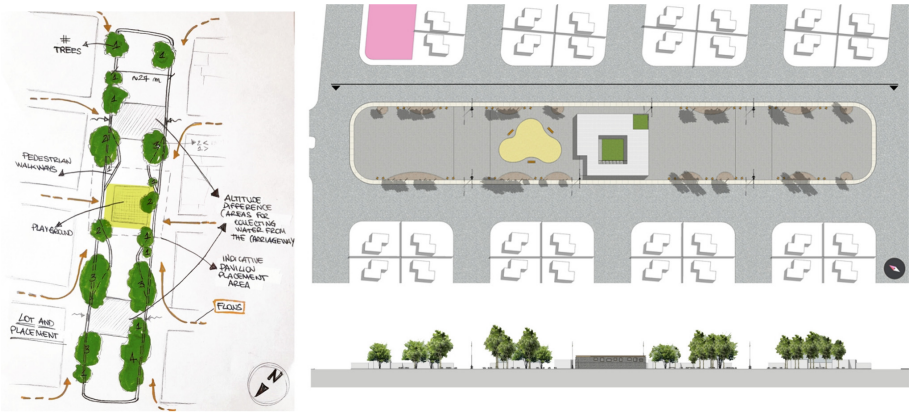

Fig. 13. Conceptual design Project 3 - The public for the collective and the occupancy of the public space. Adapted by Authors from drawings by Giulia Venanti and Ilario Piscioneri, UNIPV.

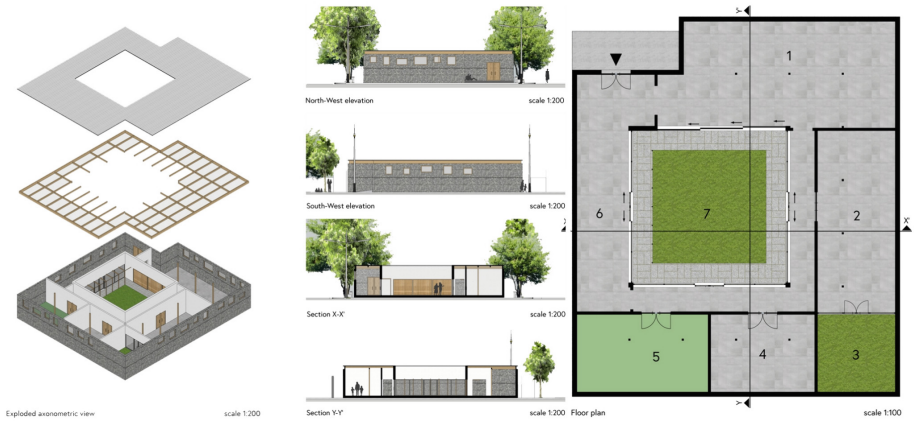

Fig. 14. Conceptual design Project 3 - The occupancy of the public space and urban occupancy through the public facilities. Adapted by Authors from drawings by Giulia Venanti and Ilario Piscioneri, UNIPV.

5 Conclusion

In this paper we introduce an overview of projects that reveals possible strategies and tactics and make visible the potentialities of architectural design as driver of critical awareness. The main contribution and novelty of this study are twofold: firstly, our research projects go beyond both theoretical research and pedagogical research. In fact, at the best of our knowledge and in view of the wide literature review performed on Ciudad Juárez, we can conclude that our study combines both theoretical approach and design project knowledge visualization. Previous valuable studies here analyzed are mainly theoretical studies or, mainly design studios related to pedagogy in architectural design such as for example the Transnational Ecologies Studio at the Taubman College [32], the Border Studio at The University of Arizona [33] and, the El Paso and Ciudad Juárez Studio Works at Rice University [34]. Secondly, our results in terms of strategies and visualization were in somehow predictive and anticipatory of what have been recently published by the ONU Habitat in collaboration with the Municipal Government of Ciudad Juárez, namely the report "Vision Ciudad Juárez 2040" [35]. Of course, the ONU Habitat is comprehensive of more urban scale, however our architectural visions are completely aligned to the results of their report and predictive respect their expected results. Moreover, using the Bernard Tcshumi's theory, our architectural design introduces the notion of use, of activities and program fostering the relationship between space and program, and in so doing trying to give a political dimension to the proposed project. Fully aware that, by its nature, no architectural project could ever influence the socioeconomic structure of a society, our projects design could be considered as Bernard Tcshumi defined Counterdesign: "*Its role is not to design a social alternative that would soon be mystified by the power groups that implement it, but simply to comprehend the official forces in an area, to predict their future and to translate them in graphical terms for explanation's sake*" [36]. By using the architect's means of expression (plans, drawings, perspectives, collages, 3D models, etc.) we intended to make clear alternative

possibilities of architecture against the conformity effects of design practices imposed by the actual patterns of urban space development. In conclusion our design proposals were aimed at creating an understanding and hope that to change the vulnerable condition of a community is possible through an active rejection of ongoing and imposed urban processes.

Finally, along with the intrinsic originality of the whole working packages of this research project, there are three crucial aspects of innovation that should be considered for future research: First, the engagement of authorities should be improved in cooperation with citizens to ensure coherence between plans and the real problems of the context. Second, implementing and deepening participation and social inclusion. To improve future projects social engagement should be expanded beyond academia to involve authorities and citizens. Third, generalization and transferability of the entire work package. Aware of the fact that vulnerability is contextual, the research framework and design phases should be improved in order to be applied and implemented in other contexts moving beyond the specific environmental scenario of this project.

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The Integration of Decarbonization and Resilience Strategies in Shaping Sustainable Cities

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Abstract. In the face of escalating climate challenges, cities are taking the lead in adopting sustainable practices to mitigate carbon emissions and enhance their resilience to environmental issues. The transition towards decarbonization not only addresses the urgent need to mitigate climate change but also contributes to building resilient cities capable of adapting to a wide range of challenges. On the other hand, resilience ensures that decarbonization efforts endure and thrive, fostering long-term effectiveness and societal backing. This mutually reinforcing relationship between the two concepts highlights the importance of combining them for a holistic and integrated approach to building sustainable and climate-resilient urban environments. This article examines the relationship between decarbonization and resilience strategies, providing a comprehensive framework to illustrate their interaction to achieve sustainable and resilient cities. The methodology of the research contains three phases. The initial stage consists of carrying out a literature review to understand the concepts. Subsequently, the findings are integrated to develop a unified conceptual framework. The final phase illustrates how the collaboration between decarbonization, and resilience contributes to achieving sustainable cities. The article highlights the need for interconnected strategies to fortify cities against climate challenges while concurrently reducing their carbon emissions.

Keywords: Resilience · Decarbonization · Sustainable Cities

1 Introduction

Climate change is a change caused by human activities in addition to the natural variability of climate [1]. Urbanization and urban areas belong to a set of worldwide, multi-scale phenomena that are profoundly altering the relationship between society and the environment and affecting both urban and earth system sustainability and resilience in complex

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ways and at alarming rates [2]. This situation necessitates a revaluation of how urban areas contribute to and are impacted by climate change, laying the groundwork for the subsequent discussion on the role of cities in global greenhouse gas (GHG) emissions.

Nowadays, the significant contribution of urban areas to global greenhouse gas emissions is highlighted [3]. Therefore, cities must respond more quickly and more effectively to anticipate and minimize the associated consequences and dangers [4]. For this reason, the United Nations Sustainable Development Goals (UN-SDGs) took the enhancement of urban resilience as one of the global sustainable development goals in 2015 [5]. By embracing the concept of urban resilience, cities can enhance their capacity to withstand and recover from shocks and stresses, improve the well-being of their residents, and create sustainable, inclusive, and liveable urban environments for future generations [6]. To explore the possibility of developing a unified framework for sustainability and resilience, it's essential to investigate the relationship between these two concepts [7]. This exploration into sustainability and resilience serves as a bridge to the global response to climate challenges, particularly the initiatives led by cities under the Paris Agreement.

The Paris Agreement on climate change has called for urgent, radical, and transformative actions in mitigation and adaptation, particularly in terms of reducing greenhouse gas emissions [8]. Cities have taken the lead in sustainability and climate crisis and are more networked than ever [9]. These cities seem to approach carbon neutrality from a broader perspective, integrating the concept under the umbrella of sustainability and resource wisdom [10]. With current demographics, urbanization, and changing climate concerns, incorporating sustainability and resilience concepts into urban planning becomes critical for decision-makers globally [11]. The proactive stance of cities in addressing climate change through sustainability and resilience underscores the necessity of understanding these concepts deeply, which leads to focused research on resilient cities.

Studies on resilient cities are aimed at establishing both practical and theoretical understandings of resilience, especially in terms of addressing challenges like urbanization and environmental catastrophes [12]. This effort gains added significance considering the growing occurrence of natural hazards, which are intensified by the effects of climate change [7], highlighting the crucial need to comprehend the interplay between sustainability and resilience.

Consequently, this paper explores the synergies between these two critical strategies, aiming to understand the collaborative impact of decarbonization and resilience on fostering sustainable urban environments. This study seeks to demonstrate how integrating resilience and decarbonization strategies can guide cities toward sustainability, bolster global climate efforts, and enhance urban resilience, ultimately leading to the development of truly sustainable cities. To achieve this aim, the main research question we seek to answer is: How can the integration of decarbonization and resilience strategies contribute to achieving sustainable cities?

This research employs various meticulous stages to integrate resiliency and decarbonization, aiming to achieve sustainable cities. This approach gathers insights into the individual characteristics of resiliency and decarbonization, identifying how these elements can be effectively integrated to enhance urban sustainability. Ultimately, to

answer the research question, this study builds a conceptual framework that helps cities to achieve sustainability goals.

2 Methodology

In this research, an extensive review of scientific publications on resilience and decarbonization was conducted, with sources including Scopus, Web of Science, Wiley, and Google Scholar. The selected papers were also examined to uncover more studies. Beginning with an analysis of these concepts, this paper is structured into three key stages as outlined in Fig. 1, with each stage building upon the previous one to address the research question. The key stages are as follows:

First Stage: Review of the Definitions of Resiliency and Decarbonization Concepts. This initial stage involves reviewing existing scholarly work to recognize these key concepts. This examination helps set the stage for analyzing the key terms and principles that will be explored throughout the research.

Second Stage: Exploration of the Interplay Between Resiliency and Decarbonization. Moving beyond the first stage, this phase focuses on recognizing how these concepts interact and contribute to each other's understanding. It involves analyzing how resilient strategies can contribute to decarbonization efforts and, conversely, how decarbonization can enhance urban resilience. The aim is to identify synergies that can inform more effective and integrated approaches to sustainable cities.

Final Stage: Synthesis and Framework Development. Building on the insights gained from exploring the interplay between resiliency and decarbonization, this concluding phase focuses on synthesizing these insights into a conceptual framework. This framework illustrates the synergy between decarbonization and resilience for fostering sustainable cities. Generally, this stage involves integrating the findings from the previous phases to formulate a sustainable city that can adapt to simultaneously advance its resilience and decarbonization goals.

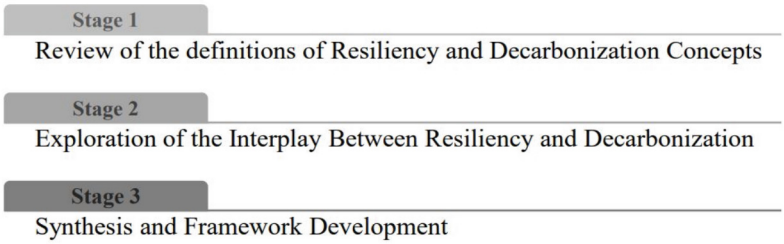

Fig. 1. Main phases of the methodology

3 Definition of Concepts

3.1 Resiliency and Resilience Cities

Notwithstanding growing popularity, the term "resilience" continues to be enshrouded in ambiguity and confusion, stemming from the diverse interpretations and approaches found in academic speech [12]. Resiliency, according to Merriam-Webster, involves the capacity of an entity to regain its original form after compression or deformation and, additionally, signifies the capability to readily recover from or adapt to adversity or change [13]. This term has a long history [2], and each discipline explains and describes the concept of resilience with a different meaning, according to their needs and priorities [14]. Originating from Holling's 1973 research on the ecology and the behavior of ecological systems, resilience was first introduced to the academic literature as "a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" [7].

Rapid urbanization, urban regeneration, immigration, and economic cycles are only a few of the diverse factors that urban areas face [11]. The city, as the most intricate social ecosystem, has been exposed to [5] urban disasters from around the globe [15]. Therefore, cities all around the world need a strategy to tackle these disasters, which is Resilient cities, that give them the ability to absorb, recover, and prepare for future shocks (economic, environmental, social & institutional) [16]. Urban resilience is one of the newly emerging yet heated urban studies buzzwords [17], and its definitions are created from different perspectives [4]. Urban resilience is a central concept in enabling cities to be prepared for disasters and unexpected events [1]. Resilience signifies a city's prowess in enduring and rebounding [12] and adapting in the face of change [18]. Urban resilience is the measurable ability of any urban system, with its inhabitants, to maintain continuity through all shocks and stresses, while positively adapting and transforming toward sustainability [14].

In the context of sustainable cities, resilience and resiliency encompass the ability of urban systems, including communities, institutions, and infrastructures, to withstand, adapt, and positively evolve in response to environmental, social, and economic challenges. These concepts emphasize the importance of designing and managing cities in ways that enhance their capacity to address shocks and stresses while promoting sustainable urban development. The criteria of resilient cities typically encompass a set of principles and characteristics that enable urban areas to withstand, adapt to, and recover from a variety of shocks and stresses. Some criteria in Fig. 2 can be broadly categorized as follows:

- Robust and green Infrastructure: Infrastructure provides critical services to communities, supporting economic functions, and serving as the first line of defense against shocks and disasters [19]. Promote green infrastructure, including parks, green spaces, and urban forests, which provide multiple benefits, such as flood mitigation, heat reduction, and improved air quality [6].
- Effective Governance: Good governance at the regional and national levels should combine features such as robustness, redundancy, recovery, conservation, sustainability, and risk mitigation to deliver enhanced resilience [20].

- Urban Form: The urban form consists of three main elements: buildings, their open space, and the streets [21].
- Spatial Planning and Integrated Development: Resilience is associated with spatial planning as the latter gives geographical expression to the economic, social, and environmental policies of local societies [22].
- Diverse and Vibrant Economy: Cities with a diverse economic base are more resilient to economic downturns as they are not overly reliant on a single industry or sector [6].
- Social Equity and Community Capacity: Resilience strategies must consider for whom resilience is being built, while simultaneously promoting the equitable distribution of social and material goods, ensuring meaningful participation and engagement in decision-making processes, and acknowledging social, cultural, and political differences [23].
- Communication and Information: Building communication in a society to spread information and increase the knowledge of citizens, there are some factors such as social networks, informal networks, and presence in social groups [24].

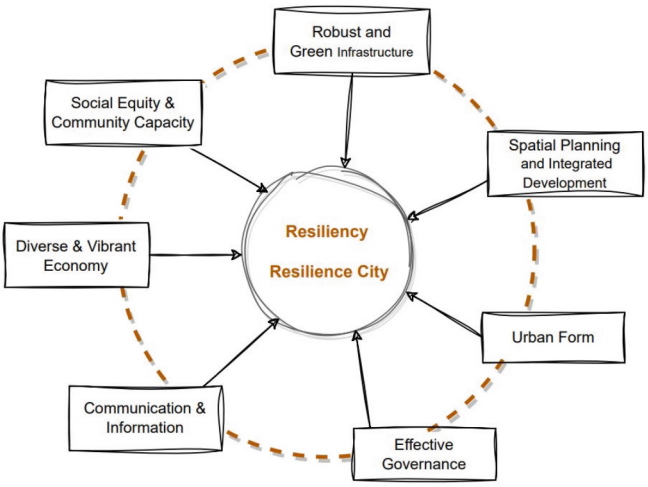

Fig. 2. Measures for attaining Resiliency

3.2 Decarbonization and Carbon-Neutral Cities

Decarbonization is the process of shifting away from carbon-based energy systems [25] which means eliminating fossil fuel use and reducing GHG emissions to zero [26]. Decarbonization involves strategies reducing the levels of carbon emissions caused by facilities, processes, or organizations, removing carbon from various sources, and overall reducing the production of carbon emissions to mitigate climate change impacts [27].

The pursuit of CO2 emission has emerged as an urgent global agenda for addressing climate change [8]. International climate policy discussions underwent a transformative

shift after COP 15, evolving from short-term, incremental actions with differentiated responsibilities to an agreement at COP 21 [28]. In the Paris Agreement, adopted during the 21st Conference of the Parties, all nations agreed on keeping the temperature rise below 2 degrees and preferably below 1.5 degrees Celsius above pre-industrial levels [29].

Urban areas consume approximately 60–80% of final energy use worldwide and generate over 70% of global GHG emissions [9]. Therefore, carbon-neutral cities are increasingly recognized as a critical step toward mitigating climate change [3]. According to the C40 Cities, a carbon-neutral city achieves net-zero GHG emissions across all sectors, including fuel use in buildings, transport, industry, grid-supplied energy, and waste treatment within city boundaries, as well as any additional sectoral emissions included in their GHG accounting boundary [30]. The definition of carbon-neutral cities involves a combination of emission reduction goals, ranging from 60 to 80 percent reductions, and offsetting or sequestering the remaining 20 to 40 percent reduction through local or global sustainable development initiatives [10]. In summary, the definition of carbon-neutral cities involves setting specific emission reduction goals, offsetting, or sequestering the remaining emissions, and integrating sustainability and resource wisdom targets in decision-making. This concept is crucial for cities aiming to achieve climate neutrality and align with international climate goals.

The process of decarbonizing cities involves a series of strategies and approaches aimed at significantly reducing or eliminating carbon emissions within urban environments. Together, these strategies create a comprehensive approach to decarbonizing cities, aiming to reduce GHG emissions, improve air quality, and contribute to the global effort to combat climate change. Some strategies for decarbonizing cities can be broadly categorized as shown in Fig. 3:

- Renewable energy adoption: At a global level, renewable energy technologies are the key to reducing emissions from electricity supply [31]. Increasing the use of renewable energy sources such as solar, wind, and hydropower within city limits can help decarbonize the energy supply.
- Green Infrastructure and Sustainable Transportation Systems: Distribution of enough infrastructure [32], and implementation of transportation decarbonization initiatives could promote the adoption of zero carbon mobility patterns as a means of mitigating climate change [33]. Incorporating green infrastructure such as parks, and green roofs, shifting towards sustainable modes of transportation, promoting cycling, and walking, and developing infrastructure for electric vehicles.
- Comprehensive Planning and Integrated Development: Integration of energy planning into urban planning and development processes [30], with an emphasis on comprehensive low-carbon urban planning for transport, energy efficiency, and renewable energy, covering housing, transport, public utilities, and commercial development [34]. Cities need to develop comprehensive plans that address all sectors contributing to greenhouse gas emissions, including energy, transportation, buildings, waste management, and land use.
- Energy Efficiency: Energy efficiency plays a key role in reducing energy consumption across end-use sectors [31]. Implementing measures to improve energy efficiency

across residential, commercial, and industrial buildings, including retrofitting older structures and enforcing green building standards for new constructions.
- Community and Stakeholder Engagement: Collaboration between different stakeholders, including government, businesses, and citizens [10] to share responsibility for achieving carbon neutrality [30]. Engaging communities, businesses, and other stakeholders in the decarbonization process through education, incentives, and participatory planning to ensure the widespread adoption of low-carbon practices.
- Financial and Economic Tools: In Europe, the development and deployment of key financial instruments (ESIF), and others are pivotal in driving the transition towards a low-carbon economy [35]. Employing financial and economic mechanisms to support decarbonization efforts, such as green bonds, environmental taxes, and public-private partnerships.
- Behavioral change: Cultivating a sense of ownership and responsibility within communities can enhance participation and drive towards adopting sustainable practices and backing efforts to cut down on carbon emissions [3]. Three main types of behavioral change included reducing excessive or wasteful energy use, transport mode switching, and Materials efficiency gains [31].

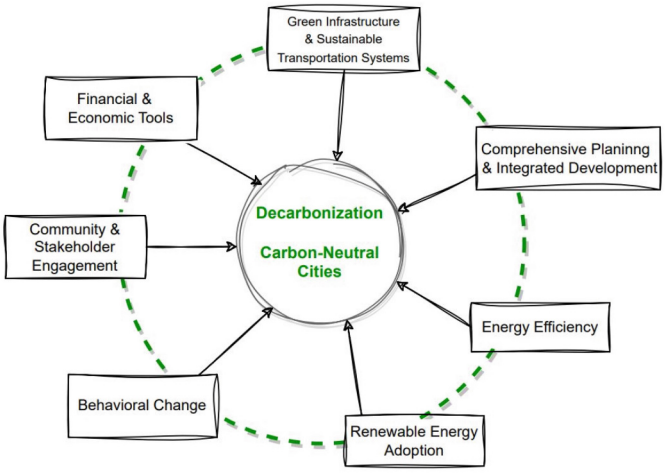

Fig. 3. Measures for attaining Decarbonization

3.3 Sustainable Cities

The subject of sustainable cities is endlessly fascinating [36]. Sustainable Cities and Communities, which are within the Sustainable Development Goals of the United Nations as Goal 11, aim to ensure inclusive, safe, resilient, sustainable urban and human settlements [37]. There are now global and local commitments to make urban areas into 'sustainable cities' through various processes of 'sustainable urban development' [36]. Specifically, cities around the world should develop and urbanize more sustainably [38]

and focus on providing essential services, clean energy, and affordable housing to all residents.

To achieve sustainable cities, key actions include removing slum-like situations, providing inexpensive transit solutions, decreasing urban sprawl, enhancing urban governance involvement, addressing urban resilience, tackling climate change issues, ensuring access to all to secure public places, and enhancing urban management through improved urban rules and regulations [37].

4 Synthesizing Concepts

Based on the definitions of concepts and measures for achieving resilient cities and decarbonization retrieved from reviewing scholarly works, this section focuses on combining findings. This integration demonstrates the impact of synthesizing these strategies for achieving sustainable cities which will be further developed in the next section.

4.1 Synthesizing Decarbonization and Resiliency

As climate change intensifies vulnerabilities in urban areas [12], challenging the capabilities of cities to sustain the burgeoning human population and protect the built environment [11], a dual approach emerges as essential. The best way to address city complexity in the face of serious climate change is to improve the city's resilience [34]. The essence of urban resilience lies in its focus on equipping cities to withstand and adapt to a variety of environmental, social, and economic shocks, particularly those exacerbated by climate change [23]. The United Nations Development Program (UNDP) highlights the importance of cities in the climate-resilient future, acknowledging that while cities are major contributors to carbon emissions, they are also at the forefront of innovation and action in reducing emissions and adapting to climate change.

Analyzing the literature reveals that resilience was originally synonymous with endurance against climate change [1]. Merging decarbonization and resilience offers a dynamic approach to addressing climate change challenges. Decarbonization shifts energy systems away from carbon-intensive sources, emphasizing renewable energy, efficient use, and reduced emissions. Although varied in interpretation, resilience fundamentally supports the abilities of systems to adapt and recover from disruptions. The synthesis of these strategies enhances adaptability to environmental shifts while actively reducing carbon footprints, creating a comprehensive response to climate change. Concepts like low-carbon living urban resilience and successful climate change adaptation have different meanings for different people [39]. This notion extends beyond mere survival, aiming for cities to thrive and evolve in adversity.

The criteria for resilient cities and the strategies for decarbonizing cities share a fundamental alignment, pointing towards a holistic approach to urban development that emphasizes sustainability, resilience, and carbon neutrality. The principles of resilient cities, including robust and green infrastructure, effective governance, and comprehensive spatial planning, dovetail seamlessly with decarbonization strategies such as the adoption of renewable energy, green infrastructure development, and comprehensive urban planning. For instance, the promotion of green infrastructure, such as parks and

urban forests, not only serves as a defense mechanism against urban shocks and stresses but also contributes to the reduction of carbon emissions through enhanced air quality and heat reduction.

Moreover, effective governance and community engagement are pivotal in enhancing urban resilience and achieving decarbonization goals. Engaging communities and stakeholders in the decision-making process ensures the equitable distribution of resources and the adoption of low-carbon practices, fostering a culture of sustainability.

Similarly, the focus on energy efficiency and sustainable transportation systems under decarbonization strategies complements the resilience aim of creating diverse and vibrant economies by reducing reliance on fossil fuels and promoting economic diversification. Through this synergy, cities can achieve a resilient and sustainable urban form prepared to face future challenges, ensuring a thriving, inclusive, and carbon-neutral urban environment for current and future generations. This integrated approach exemplifies the essence of sustainable urban development, where resilience and decarbonization are not seen as separate endeavors but as the interconnected facets of the same goal: building sustainable, resilient cities capable of withstanding the challenges of the 21st century and beyond.

The relationship between carbon-neutral cities and resilient cities is deeply intertwined, emphasizing the crucial role urban areas play in addressing climate change and enhancing sustainability. Carbon-neutral cities aim to reduce greenhouse gas emissions to zero through a combination of energy efficiency measures, renewable energy sources, and offsetting emissions, thereby tackling the root causes of climate change. Resilient cities, on the other hand, focus on preparing for, responding to, and recovering from a range of climate-related and other shocks and stresses, ensuring that urban systems can continue to function and thrive in the face of challenges.

4.2 Toward Sustainable Cities-Synergy Between Decarbonization and Resilience

This section delves into the indispensable role of harmonizing decarbonization and resilience strategies for achieving sustainable cities. The quest for sustainable cities represents a crucial intersection of environmental stewardship and urban development, drawing from the principles of both decarbonization and resilience. The Sustainable Development Goals (SDGs) of the United Nations, particularly Goal 11, underscore the importance of creating inclusive, safe, resilient, and sustainable urban environments [37]. This goal is an aspiration and a necessary evolution towards sustainable urban and human settlements, requiring concerted global and local efforts [36].

Considering increasing urbanization and sea level rise among the main urban challenges that many cities around the world face, four main aspects have been identified that cities should prioritize in the upcoming years to accelerate sustainable and low-carbon transitions and to build resilience [38]. Coping with the challenges of ever-shifting the climate of the earth contextualizes the importance of resilience in sustainable development [7]. By integrating decarbonization and resilience strategies, cities can create synergies that enhance their sustainability, liveability, and ability to thrive in the face of future challenges. This holistic approach to urban development is essential for addressing the complex challenges of climate change, urbanization, and resource scarcity.

The criteria for resilient cities, paired with decarbonization strategies, create a comprehensive framework that can directly contribute to achieving sustainable cities. This holistic approach addresses a spectrum of urban challenges, from social equity to environmental sustainability, offering key actions for transformative urban development. The emphasis on robust and green infrastructure and the adoption of renewable energy sources not only mitigates climate change impacts but also improves living conditions, thereby contributing to the removal of slum-like situations. Green spaces and renewable energy projects can be integrated into these areas, enhancing liveability, and providing clean energy, which is a step towards inclusivity and sustainability.

Moreover, sustainable transportation systems and the focus on energy efficiency align with providing inexpensive transit solutions. By promoting cycling, walking, and the development of infrastructure for electric vehicles, cities can decrease reliance on fossil fuels, reduce emissions, and offer affordable transit options. This strategy also contributes to decreasing urban sprawl by encouraging more compact, efficient urban forms and reducing the need for extensive travel.

Enhancing urban governance involvement is central to both resilience and decarbonization efforts. Effective governance plays a crucial role in fostering the development and implementation of comprehensive plans and policies. These strategies prioritize three key areas: sustainability, resilience, and community engagement. This collaborative approach ensures that resilience and decarbonization are not just technical or environmental targets but are integrated into the broader goals of social equity and sustainable urban management.

Addressing urban resilience directly tackles climate change issues by preparing cities to withstand, adapt to, and recover from environmental shocks. The criteria for resilience, such as diverse and vibrant economies and community capacity, ensure that cities are equipped to address both current and future climate challenges. This proactive stance on resilience contributes to creating secure public places by making them more adaptable to climate-related and other shocks, ensuring public spaces remain accessible and safe for all.

Additionally, the synergy between resilient and decarbonized cities enhances urban management through improved urban rules and regulations. By embedding resilience and decarbonization into urban planning and governance frameworks, cities can adopt innovative regulations that support sustainable development goals. These might include zoning laws that encourage green infrastructure, building codes that mandate energy efficiency, and policies that support renewable energy adoption and sustainable transportation.

Ultimately, the intertwined strategies of urban resilience and decarbonization provide a robust pathway toward sustainable cities. By focusing on these integrated approaches, cities can tackle a wide range of issues from environmental degradation to social inequity, paving the way for urban environments that are inclusive, safe, resilient, and sustainable. This holistic perspective is essential for addressing the complex challenges of the 21st century, ensuring that urban development is both sustainable and equitable.

5 Conceptual Framework

The conceptual framework depicted in Fig. 4 synthesizes and visually represents the intricate interplay between resilience and decarbonization to achieve sustainable cities. This framework elucidates the dynamic connections among various elements.

This conceptual framework is crafted by integrating factors and measurements outlined in earlier sections, placing the goal of sustainable cities at its heart. To realize sustainable cities, the framework incorporates eight interconnected activities, each vital for sustainability. Additionally, it introduces a ninth critical activity that enhances the original eight by focusing on the adoption of renewable energy, improving energy efficiency through decarbonization strategies, and optimizing urban form based on resilience principles, which significantly boost energy efficiency. This comprehensive approach underscores the importance of these interconnected activities in achieving sustainable urban development.

Achieving sustainable cities involves two main activities: addressing climate change through decarbonization and the creation of carbon-neutral cities and enhancing urban resilience to ensure cities can withstand and recover from various challenges. Moreover, the endeavor to establish carbon-neutral cities and enhance resilience directly drives actions that align to achieve sustainable cities.

Factors such as robust green infrastructure and sustainable transportation, derived from both resilience and decarbonization concepts, play a crucial role in providing affordable transit solutions and ensuring equitable access to secure public spaces. Social equity and community capacity, rooted in resilience principles, are essential for facilitating access and improving urban management. These factors also intersect with other aspects of decarbonization and resilience, including fostering a diverse and vibrant economy from a resilience perspective and utilizing financial and economic tools from decarbonization efforts, all of which contribute to enhanced urban management.

Other important categories include factors that focus on resilience, such as communication and information, as well as effective governance. Additionally, strategies aimed at decarbonization, such as promoting behavioral change and engaging communities and stakeholders, play a significant role. These elements contribute to both urban management and governance involvement, highlighting their interconnectedness and impact on sustainable development. Moreover, spatial planning, comprehensive planning, and integrated development, common to both decarbonization and resilience, play a significant role in addressing challenges like removing slum-like conditions and reducing urban sprawl.

To make these concepts more visually accessible, we employ a color-coding system in our depiction. Factors that contribute to decarbonization and the goal of carbon-neutral cities are marked in green. In contrast, factors related to resilience and the creation of resilient cities are shown in dark orange. For categories that incorporate the elements of both resilience and decarbonization, an olive color is used. This color scheme emphasizes the interconnectedness of these factors and their collective importance in driving sustainable urban development. Using this color-coded framework, our goal is to offer a clear and detailed insight into the synergy between decarbonization and resilience strategies, demonstrating their combined role in promoting the development of sustainable cities.

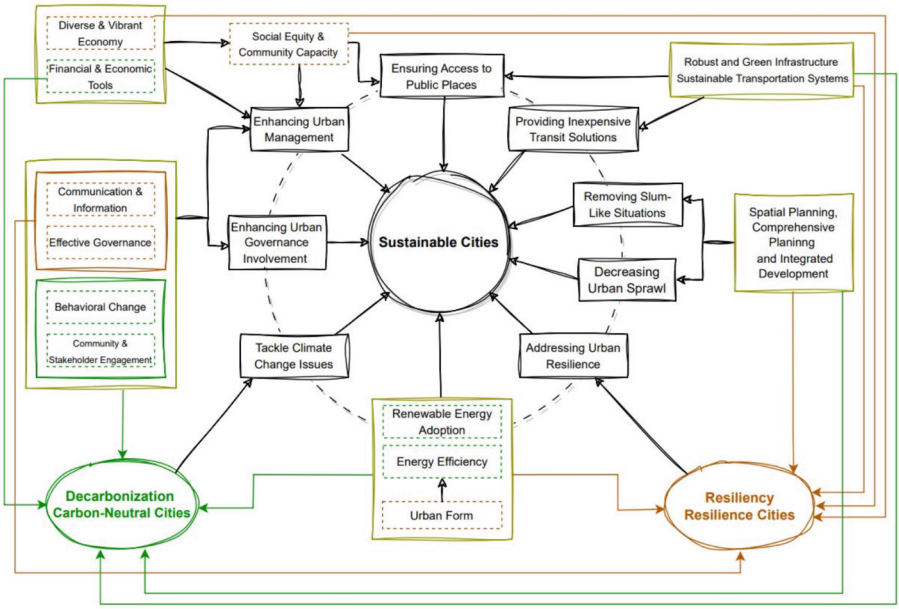

Fig. 4. Conceptual Framework

6 Conclusion

Cities need to develop comprehensive climate action strategies that enhance their emergency response capabilities, ensuring the safety and security of urban dwellers during severe climate-related incidents. Integrating decarbonization and resilience is crucial, transcending theoretical models to address the practical challenges of increasing environmental unpredictability. Implementing these strategies in tandem lays a robust foundation for addressing the symptoms and root causes of climate change. Through focused decarbonization initiatives, cities can significantly reduce their carbon footprints, thereby minimizing their ecological impact. At the same time, boosting urban resilience equips cities to handle and recover more effectively from the negative impacts of climate-induced phenomena, securing a sustainable urban environment for future generations. This dual approach mitigates immediate climate risks and promotes long-term urban sustainability, ensuring a viable future for its residents.

The ongoing urbanization and growth of urban spaces are significantly altering the relationship between society and the environment, leading to concerning impacts on urban sustainability and resilience. Well-planned and managed cities can provide an optimal and efficient living space for their large populations, not only achieving sustainability and liveability but also enhancing overall health and well-being. Achieving sustainable cities requires a synergy between decarbonization and resilience strategies. This approach addresses the urgent need to reduce carbon emissions and enhances urban systems' ability to withstand and adapt to climate-related and other challenges.

Ultimately, achieving sustainable and resilient cities is a collective endeavor that requires the engagement of all stakeholders. It is through the shared vision and concerted efforts of the global community that the ambitious goal of creating urban environments that are not only sustainable and resilient but also equitable and flourishing can be achieved. This article serves as a call to action for cities worldwide to embrace the integration of decarbonization and resilience strategies, paving the way for a sustainable future.

Future studies could delve into the case studies of cities that have successfully implemented these integrated strategies, providing valuable insights and best practices. Moreover, there is a necessity for further quantitative studies to gauge the effects of integrated decarbonization and resilience strategies for urban sustainability outcomes. Developing metrics and indicators to assess the effectiveness of these strategies in reducing carbon emissions, enhancing resilience, and improving the overall quality of life for urban residents would significantly contribute to the field. This would also aid in identifying gaps and challenges in current approaches, informing the development of more targeted and effective strategies.

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MOdels and Indicators for Assessing and Measuring the Urban Settlement DeVElopment in the View of ZERO Net Land Take by 2050 (MOVEto0 2024)

Planning Without Shared Strategies. Impacts and Perspectives Along the Abruzzo Adriatic Coastal Belt

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Abstract. The Italian legal framework for protecting land and curbing its consumption is currently very heterogeneous and complex. In addition to the outdated National urban planning laws, there are various regional and provincial laws on land management, each with its own technical and administrative peculiarities. This diversity is even reflected in the urban planning instruments of municipalities in the same region and affects the ability of regions to monitor and manage urban dynamics in line with strategic objectives. The issue of land take is an example of the challenges posed by the lack of a comprehensive national framework, leading to a multiplicity of regional regulations. This has led to ambiguities, uncertainties, and different interpretations of the phenomenon across regional boundaries. Despite the European Union's goal of achieving zero net land take by 2050, the Italian legal framework remains fragmented, as numerous legislative proposals have not received final approval at the national level. In the Italian spatial planning system, municipal planning plays a decisive role in understanding future settlement developments. However, the complexity of the legal framework and insufficient technological resources often limit planning to individual municipalities. This study presents the results obtained by analyzing the municipalities located along the Adriatic coastal stretch of the Abruzzo region, examining the contents of the current urban plans of the 19 municipalities included in this area. It uncovers critical issues and contradictions that could affect ecological connectivity and emphasizes the need for strategic planning to maintain environmental integrity in these areas.

Keywords: Land take · Territorial planning · Coastal urbanization

1 Introduction

The Italian regulatory landscape on the issues of soil protection and containment of its consumption is today extremely heterogeneous and highly articulated. An outdated national urban planning law (Law No. 1150/42) is flanked by regional and provincial land management laws, each with its technical-administrative peculiarities. This heterogeneity can be found within the urban planning instruments of municipalities in the

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same region and, inevitably, is reflected in the ability of the regions to implement the monitoring and control of urban dynamics, because of their strategic objectives [1]. The issue of land use provides a striking example of how the absence of a national framework law has led to a proliferation of regulations that have contributed to creating ambiguities, uncertainties, and ways of interpreting the phenomenon that changes according to regional borders. This system of distortions is particularly evident in Emilia Romagna, where ISPRA (Italian National Institute for Environmental Protection and Research) data indicates land take, while according to current regional law, such consumption is considered null due to exemptions granted. These exemptions often render measures to contain the phenomenon ineffective, as they allow authorities to maintain outdated and oversized urbanization forecasts compared to the actual needs of the territory [2]. The goal of achieving a zero soil balance by 2050 remains a cornerstone of European policies, but it is still far from being framed by the Italian regulatory maze. At the national level, as many as 54 bills were presented to the chambers (between 2010 and 2022) without ever reaching final approval. While many regional laws aim to limit land take, they have definitions that do not consider land use in urbanized areas or land designated for urbanization as such, even if it is still vacant. This approach, which differs from established definitions at the national and European levels, can encourage further urbanization disguised as the reuse of already occupied land, effectively contributing to land take and loss of ecosystem services. [3–6]. Several European countries have taken proactive measures to combat land degradation and promote sustainable urban development. The introduction of green belts, environmental constraints, ecological corridors, and green networks reflects an integrated approach to urbanization [7]. Through mitigation strategies and ecological compensation, these countries have effectively reconciled the need for urban expansion with the protection of the environment. Germany focuses on energy-efficient refurbishment and reshaping peripheral districts, while France pursues an ambitious goal of achieving zero artificial development by 2050. Spain prioritizes urban rehabilitation, and its Agenda Urbana Española encourages active local participation [8]. In the Italian territorial planning system, where the strategic level is either absent or weakly coherent, municipal planning plays a fundamental role in understanding potential trajectories of future settlement development. However, the heterogeneity found in the synoptic descriptions of various types of land use, as well as the complexity in articulating building regulations, does not allow for a framework beyond a single municipality's administrative limits. An approach that could overcome this limitation is to compile a mosaic of municipal urban planning tools in the area of interest (province, region, or specific geographic extensions). This approach allows for the construction of a tool capable of analyzing data and processing information on a larger scale than that of a single municipality, as well as representing a possible scenario of territorial evolution soon, through the classification according to zoning types, by Ministerial Decree No. 1444/68. The compilation of municipal urban planning tools is inherently a rather complex operation in both technical and informational terms for several reasons. Firstly, there is often a technological inadequacy in drafting the municipal tool, which requires the use of various techniques (and software) for final standardization. Territorial governance processes, regardless of the scale at which they operate, require a large amount of data and information from diverse sources, each of which often has a different encoding.

The lack of standardization generates problems not only of a technical nature but also economic and managerial [9–11]. The reading of the transformative potential of a territory expressed in plans, as already emphasized, represents indispensable information in the perspective of achieving sustainability goals imposed at the European level. This study presents the results obtained by analyzing the territories of municipalities located along the Adriatic coastal stretch of the Abruzzo region, examining the contents of the current urban plans of the 19 municipalities included in this area. This choice is linked to the environmental and ecological importance characterizing this territory. The absence of careful strategic planning and the limited action of Park Plans in these areas could generate negative effects, particularly in connection areas. Therefore, the proposed work reconstructed the basic mosaic of urban planning tools as well as an advanced one (analysis on volumes yet to be implemented) for some municipalities. The analysis conducted highlighted several critical issues and contradictions present in the different municipal tools that could significantly compromise the ecological connectivity of these areas.

2 Case Study

This work focuses on one of the most active geographical areas in terms of urban transformations: the coast. In particular, the analysis was conducted along the Adriatic coastal stretch of the Abruzzo region in Italy (Fig. 1). This system extends linearly for approximately 130 km and covers the territory of 19 out of the 305 municipalities in Abruzzo, totaling 640 km^2 (approximately 6% of the regional territory). These coastal communities have different geomorphologic features that mix maritime characteristics with terrestrial formations. Francavilla al Mare, in particular, is characterized by a maximum altitude of 169 m above sea level.

The importance of these areas is clearly and directly understood by examining the economic and demographic dynamics of the last 10 years: between 2013 and 2023, the Abruzzo region has seen an overall decrease in its population of almost 40,000 units, while coastal municipalities have recorded an increase of approximately 9,000 residents, equivalent to about 900 new residents every year. It's as if each municipality had registered an average annual increase of about 48 new residents. Almost all the municipalities analyzed have a population of over 10,000 inhabitants, among which certainly stand out the provincial capital Pescara, which, with its approximately 120,000 residents, is the most populous municipality in Abruzzo, as well as Vasto and Montesilvano with their approximately 40,000 residents. Only two of the 19 municipalities analyzed have a population of less than 3,000 units (Rocca San Giovanni and Torino Di Sangro). As for population density in coastal areas, the difference compared to regional and national values is substantial. Only the municipality of Casalbordino has a value comparable to the regional one (about 120 inhabitants/km^2), while the aforementioned municipalities of Rocca San Giovanni and Torino Di Sangro have values of around 100 inhabitants/km^2. However, in this area, there are municipal entities with population densities comparable to those of the main hinterlands of Italian metropolitan areas that have a population density greater than 1000 inhabitants per km^2. From a morphological point of view, the Abruzzo Adriatic coastline is quite uniform, with almost all of the municipalities' territory represented by flat formations, with low sandy beaches and a hinterland that is also

flat or low hilly, which has facilitated over time both the construction of infrastructure and productive and residential settlements.

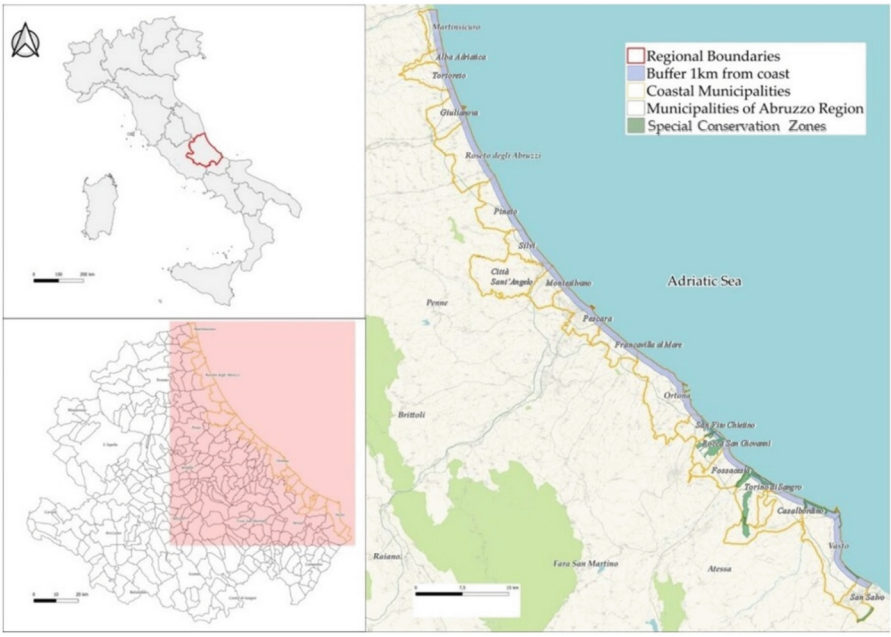

Fig. 1. Location map of the study area.

The presence of important communication axes (Highways A1, A24, and A25 together with the high-speed railway line) has allowed the growth and strengthening of urban centers over time. Apart from the morphologically disadvantaged areas (e.g., rocky promontories), the Abruzzo coastal settlement can be considered as a single linear stretch characterized predominantly by forms of urban sprawl (although with different modes from the European one) that dominated the settlement development of the 1960s-1970s, interspersed with manifestations of more recent interventions (sprinkling). From an economic point of view, coastal municipalities contribute to over a third of the regional taxable income, although only seven municipalities have a per capita income comparable to the national average value for the period (the reference year 2021). Even though the anthropic aspect (not only from an urbanization point of view but also agricultural) appears to be dominant, it is still possible to identify areas that preserve important natural features. It should be noted that apart from a couple of Special Conservation Zones (SCZs), there are no other protected areas; therefore, the safeguarding of these residual traits is often entrusted to other regulatory forms that nevertheless allow margins of transformability (e.g., Landscape Plan). These natural areas are mainly concentrated south of Ortona, where the morphology and the reduced sandy beach have slowed down the more intense forms of urbanization along the coast but also along the hydrographic network where well-structured riparian zones along the rivers are still present.

The presented work analyzes the 1 km coastal strip as this stretch is the most affected by urban phenomena related to maritime economies, as also demonstrated by recent studies. Starting from the current settlement configuration, the work then shows what could be the new urban layout of this area based on the predictions of the current municipal urban planning tools [12]. Since there is currently no strategic plan for the area, each municipality implements its transformative policies within its boundaries, seeking on the one hand to meet the needs of the communities living in these places and on the other hand to increase the tourist offer, which represents one of the main sources of the local economy.

3 Materials and Methods

The reconstruction of the geography of urban settlement and that envisioned in the urban planning instruments of the 19 municipalities under study required the use of data from various sources. The current level of soil sealing, as well as its evolution over time (2006–2022), was deduced from the ISPRA portal. The development of the Planning Tool Mosaic (PTM) involved thorough research into the current urban planning instruments utilized by the municipalities under study. This research was conducted using institutional portals where accessible, or by directly contacting the technical offices of the municipalities involved in the study. This facilitated the reconstruction of the trend scenario in urban planning as reported in them. The techniques for crafting this pivotal tool can be extrapolated from various articles in the literature [9, 11, 13–17]. In this specific instance, however, endeavors were made to streamline the transformative typologies incorporated in the plans, aiming for a clearer and more immediate comprehension of the land use associated with these areas, rather than solely referencing the zones outlined in Ministerial Decree No. 1444/68. The comparison with the zones identified by the Ministerial Decree and the typological macro-categories is delineated in Table 1.

Table 1. Areas identified by the DM and typological macro-categories.

Macro-Category	Zone typology
Residential	B, C
Productive - Touristic	D
Services	F, S

The exclusion of A zones was due to their complete urbanization, with coverage ratios nearing 100%, permitting only redevelopment or restoration interventions without the use of new land. Conversely, industrial zones and areas related to tourist-receptive land uses were incorporated into the productive-touristic macro-category. Utilizing specific GIS techniques, the residual plan was reconstructed, and the progress status regarding the predictions outlined in the plans was quantified as a percentage. This analysis encompassed all three identified macro-categories, offering immediate insight into the unrealized transformative potentials across the entire coastal strip and within each municipality.

This method proves highly advantageous, facilitating the delineation of individual entity policies and aiding strategic planning aimed at the protection and conservation of coastal environments.

Figure 2 shows a zoomed-in view of the analyzed study area is depicted, showcasing the Planning Tool Mosaic classified according to the macro-categories described in Table 1.. In Fig. 2.a), zooming in on the study area clearly distinguishes the different macro-categories and thus takes a detailed look at the territorial distribution. Figure 2.b) and Fig. 2.c) depict a schematic representation of a residential area. Specifically, in Fig. 2.b), the current urbanized area is illustrated (buildings in black, roads in gray, and public green spaces in green), while Fig. 2.c) highlights the so-called residual urban potentiality, which represents the area of the urban plan that has not yet been implemented. This visualization provides a detailed insight into the remaining urban potentiality of each municipality and highlights the areas that are not yet used according to the urban plan. In this study, the percentage of residential, productive-touristic, and service zones within each of the 19 coastal municipalities was analyzed, along with the percentage of these categories within the buffer zone established one kilometer from the coastline. Data from the land use plans of each municipality was then used to calculate the percentage of each category in the planned area within the one-kilometer coastal zone. These results were then compared with the residual urban potentiality of each municipality.

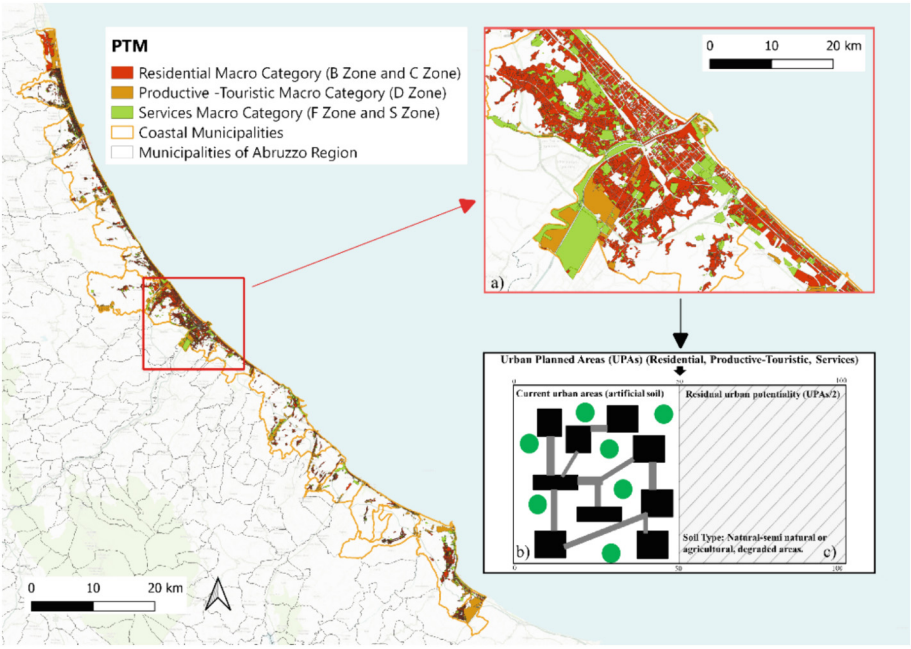

Fig. 2. PTM of coastal municipalities. a) Zoomed-in view of the analyzed study area. b) Schematic representation of a residential area. c) Residual urban potentiality.

4 Results

The first interesting result arises from the ISPRA land take data analysis for the investigated period. This result confirms what was previously reported about the importance of these municipalities in the Abruzzo regional context and their role in transforming the soil (Fig. 3).

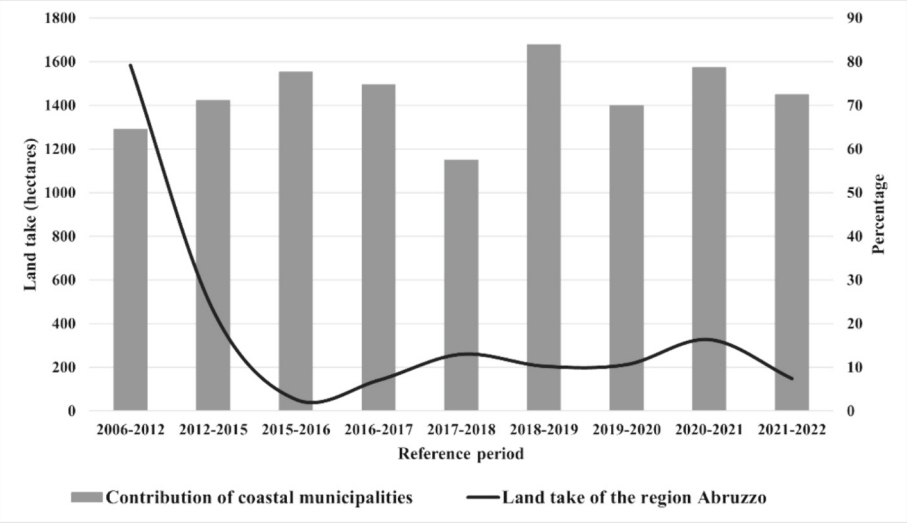

Fig. 3. The percentage contribution of coastal municipalities in Abruzzo (histogram bars) compared to the total land take of the region (black line).

The percentage relative to the total consumed has remained nearly constant, despite a fluctuation in land take levels in the region (from 2,60 km^2 per year in the initial period to 1,40 km^2 per year in the latest survey). Figure 3 was designed to provide an overview of the trend in land take in coastal municipalities compared to the entire region, highlighting both the absolute amount of land take and the percentage contribution of coastal municipalities. The graph is intended to clearly show the evolution over time of land take and the contribution of coastal municipalities. The choice to use hectares to represent land take and percentages for the contribution of coastal municipalities was made to highlight both aspects complementarily.

Figure 3 shows how coastal municipalities are responsible for an average of 70% of the entire regional land consumption, with a peak of 84% recorded between 2018 and 2019 and a minimum of approximately 60% observed in the previous year. It should be noted that these areas comprise approximately one-third of the regional population. The lack of a strategic vision for the entire coastal axis is evident from the analysis of municipal urban planning instruments. Despite maintaining the same morphological conditions (except for some specific areas), as one moves towards the inland, the plans concentrate a large part of the transformative provisions within the first kilometer from

the shoreline. Figure 4 shows that 38% of areas are designated for residential, 42% for tourist-productive purposes, and as much as 46% of services, are located in this zone.

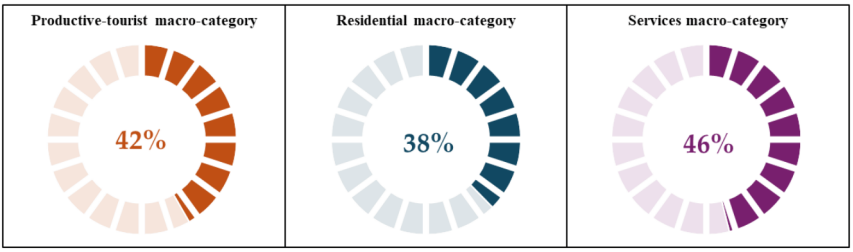

Fig. 4. Percentage share of transformative forecasts contained in plans located within the first kilometer from the coastline.

There is a total of 55 out of 136 square kilometers of the total land use allocations outlined in the plans within the first kilometer (Fig. 5). The municipal-level analysis reveals peculiarities, such as in the case of Francavilla al Mare, where almost all residential land use areas are situated within the first kilometer, along with 70% of those designated for productive-touristic purposes. Concerning services, the town of Pineto records the highest value (90%), followed by the aforementioned municipality. When analyzing the overall distribution of the three main categories of destinations, it becomes clear that 40% of the destinations are concentrated in only two municipalities (Martinsicuro and Vasto). It is also worth noting that these two municipalities, together with Ortona and Pescara, host 40% of all service-related destinations. The presence of important ports, both commercial and tourist, in these municipalities, has influenced the spatial planning policies reflected in the urban plans.

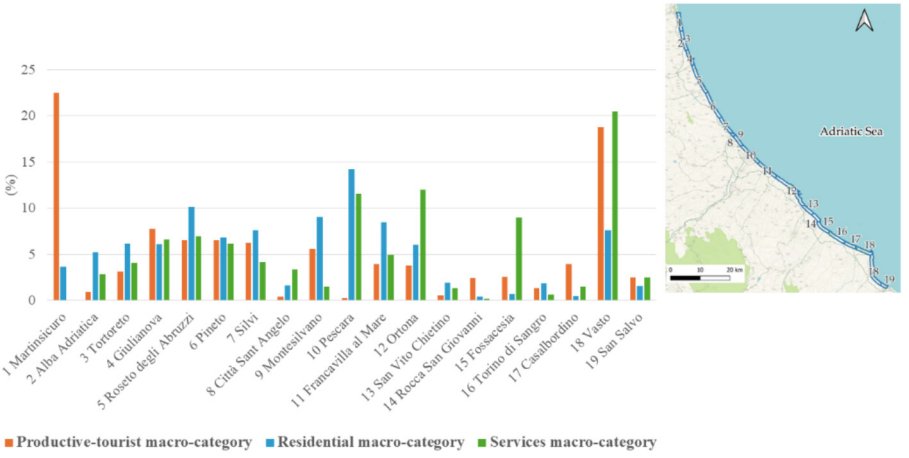

Fig. 5. Distribution of macro-categories into municipalities, ordered from north to south in a latitudinal direction.

After examining the orientation of urban development policies at the municipal level and within the coastal strip within 1 km of the coast, the existing plan was evaluated. This allows us to understand the transformation potential of each municipality and to visualize the possible reshaping of the coastal strip resulting from the implementation of the provisions of the current territorial governance instruments. For this reason, the current level of soil impermeabilization [3] (based on ISPRA 2022 data) and that of each zonal macro-category for each of the 19 municipalities included in the study were evaluated. Currently, there are just under 32 km^2 of impermeabilized surface along the coastal strip within 1 km from the coastline, with an impermeabilization density of 27%, three times the national value. Overall, 37% of macro-categories intended for productive-touristic purposes are implemented, along with 45% of those for residential use and 21% of those intended to accommodate various types of services (Fig. 6).

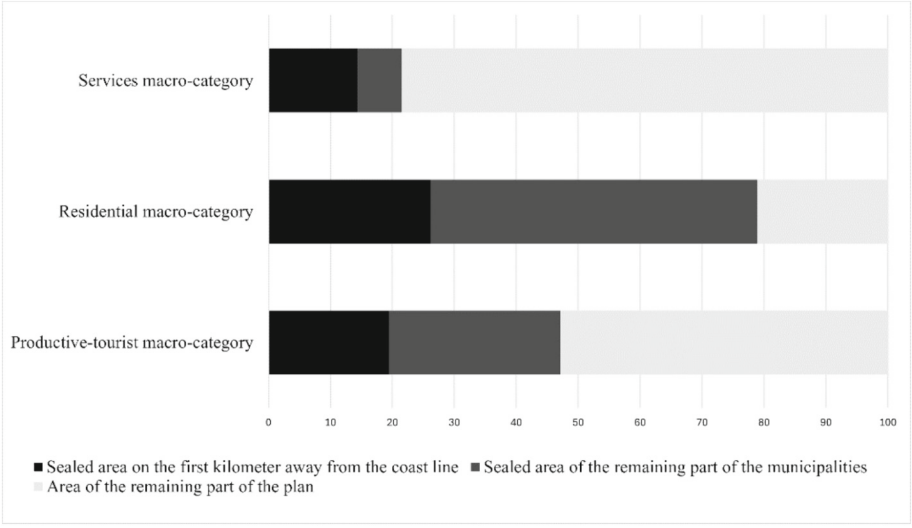

Fig. 6. Distribution of consumed land in the municipality with a focus on the first kilometer from the coast (black) and the remaining percentage still available (light gray).

The full implementation of all the planned provisions would result in the area under study reaching a 46% urbanization rate, which corresponds to almost half of the area earmarked for urban use. Here too, the picture varies considerably at the municipal level. For example, there are municipalities, such as Rocca San Giovanni, where only around 10% of the land earmarked for each macro-category of land use has been implemented. As far as the category of land earmarked for productive-touristic use is concerned, only a few municipalities have implemented around 50% of the planned areas, while the figures in other municipalities are over 60%, with peaks of over 90% still available. The same applies to land earmarked for residential purposes, with a larger number of municipalities achieving percentages of between 40% and 60%. However, the services category shows the highest availability of land still to be realized, with almost all municipalities showing values of over 70%. Figure 7 illustrates the development of these values in geographical

order from north to south and shows an interesting pattern. It can be observed that the curve in terms of services shows a similar trend in all coastal municipalities, with a slight increase in the municipalities of Vasto and San Salvo in the south of Abruzzo. The curve relating to the availability of land for productive-tourist use shows a higher availability in the first section (especially in the municipality of Alba Adriatica), followed by a decrease along the stretch from the municipality of Pineto to Montesilvano (values between 60% and 70%). From there, residual availability increases until it reaches a new peak in the area between the municipalities of Rocca San Giovanni and Torino di Sangro (values around 80%), which continues in the municipalities to the south up to the border with Molise. The curve related to residual residential availabilities follows a different trend from the previous ones. As depicted in Fig. 7 (in light gray), for most of the Abruzzo coastal sector (from Tortoreto to Ortona), values are below 60%, while greater residual availability characterizes the last stretch, the southernmost one between the municipalities of Fossacesia and San Vito Chietino. Values then decrease again in the municipalities of Vasto and San Salvo, with percentages falling below 60%.

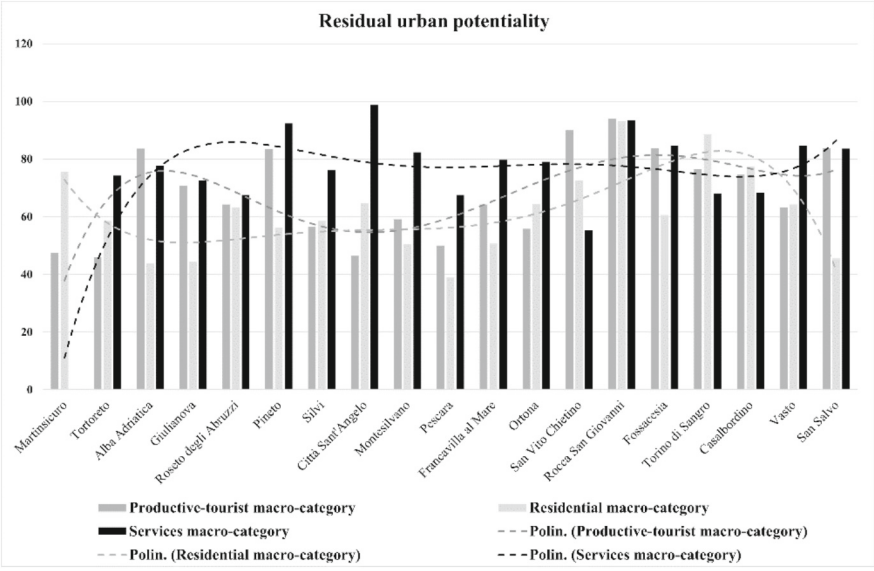

Fig. 7. Trend of the residual urban potentiality in the municipalities of the Abruzzo coast for the three macro-categories of intended use investigated.

5 Discussion and Conclusion

The plan to protect coasts from erosion, climate change impacts and pollution is critical to coastal zone management planning. It outlines the programmatic and executive framework for resource allocation and the approval and implementation of measures.

This tool addresses specific coastal protection planning issues by incorporating considerations of climate change mitigation and adaptation, coastal marine pollution, and beach activities. The main objective is to manage risks in the Abruzzo coastal area by anticipating potentially harmful events and planning measures to mitigate their effects. Despite the consideration of environmental aspects, the plan focuses primarily on coastal protection and aims to maintain the dynamic balance of the beaches and improve environmental quality [18]. However, the issue of coastal land take is not directly addressed, overlooking its potential role as one of the primary drivers of accelerated erosion, loss of natural habitats, water pollution, increased flood risk, loss of ecosystem services, and negative impacts on marine biodiversity. These phenomena can have significant environmental, social, and economic consequences for coastal communities, underscoring the importance of sustainable coastal land management. In contrast to other countries (e.g. [19]), Italy lacks active protective measures against the increasing transformation of coastal areas. Many regions are addressing this gap with integrated planning and management measures aimed at protecting public use and sensitive areas [20]. Coastal areas, characterized by high ecological value and significant human pressure, are inherently fragile systems subject to complex and delicate dynamics. Current planning often lacks a systemic view, which is exacerbated by oversized transformation projections by municipalities. To align municipal planning with environmental protection, a strategic approach that goes beyond regional boundaries is required. The territorial coordination plan can help to develop dynamic coastal scenarios and take preventive action. Urban rebalancing and sustainable management of coastal tourism could reduce the transformation pressure on the plans and bring them in line with European objectives to curb land take. Coastal environments are inherently fragile due to their high ecological value and intense human pressure. They are highly dynamic systems with delicate balances constantly threatened by human transformations [21].

The work carried out has shown that even today there is still an approach to planning without a systemic vision, which can be traced back to short-sighted policies and a lack of uniform perspectives. The high decision-making power of municipalities in urban transformations is certainly the cause of the observed state of affairs, and the overestimation of transformation projections found in all the municipalities studied only increases the risk of permanently losing the remaining natural assets and the essential ecosystem services they provide. The strong attraction of this coastal area leads to a high demand for anthropogenic use of these areas, which the municipalities continue to meet, with few forms of active protection [22] on the Abruzzo coast today (e.g. Natura 2000 sites, various protected areas). Forms of intensive tourism certainly accelerate coastal erosion [23], and every year there are numerous projects to dredge and fill sandy beaches (at considerable cost to the municipality) so that operators can start economic activities. The coastal protection plan itself aims to protect the integrity of the coast by providing for appropriate work in certain areas. Although it is equipped with a strategic vision, the forecasts of the municipal urban planning instruments are not taken into account or modified. Studies on erosion dynamics and wave propagation along coastal areas are well-documented. Coastal defense plans should transcend regional boundaries and work on physiographic units [3], guided by strategic visions for municipal planning in environmental safeguarding. Therefore, it is important to emphasize the absence of regional

planning that imposes a uniform approach to coastal management work. Although a coastal defense plan exists, it only intervenes in response to damages already occurred, without implementing preventive measures. This constitutes the core of the problem. The region, as the supervisory authority, lacks sufficient influence over local planning, particularly on individual municipalities. This lack of coordination underscores the importance of our work on physiographic units as a method to preserve the coast. It is clear that this requires broad involvement, unifying different regions and municipalities under a single strategy. If each municipality continues to act autonomously, significant progress will not be achieved. New political dynamics are necessary to transcend the logic of individual municipal interests. In this regard, the PTM is a crucial knowledge tool for building potential coastal dynamic scenarios and acting preventively [13]. Urban equalization measures and unified regional coastal tourism management can help reduce the ongoing transformative overload of plans, far from achieving important land take containment objectives set by Europe. In conclusion, it is evident that the synthesis employed, through both basic and advanced mosaic techniques, allows for a highly effective comparability among different municipalities. More importantly, it leads to a comprehensive measure of planning in the plans, potentially expressible over time as a transformative load on the territory and the environment. Essentially, it operates at a territorial scale of strategic level, which is certainly not at the municipal level, where often there is no awareness of the transformations planned or carried out in neighboring areas. Specifically, the advanced PTM mode becomes an essential knowledge level for the implementation of any future land consumption containment policies, in response to pressures from European bodies, as well as national and international sustainability policies. Such policies cannot disregard a detailed and thorough analysis of the implementation status of the current urban planning instrument; further urban transformations can only be justified by genuine urban needs, but their fulfillment requires a rational urban organization compatible with the territory's resources. This underscores the need to strictly avoid generic or contradictory design schemes that may arise in the absence of an overall strategic framework like that represented by the PTM.

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Investigating Avalanche Risk Impact on Accommodation Facilities in the Municipalities of Abruzzo Region

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Abstract. The increase in outdoor recreational activities, particularly ski tourism and trekking, has led to a significant intensification of anthropic presence in mountain regions, with a consequent growth in demand for facilities and infrastructure. This trend, also observed in Abruzzo region, has caused the urban expansion, in and near avalanche-prone areas, increasing the risk to human settlements. Catastrophic events, such as the tragic disaster involving the Hotel Rigopiano in the municipality of Farindola (Abruzzo, Italy) on 18 January 2017, highlight the urgency of addressing avalanche risk. Avalanches, defined as a sudden instability of the snowpack and its subsequent sliding down on a slope, pose a serious threat to settlements, residential areas and infrastructure. Legislative measures, such as the Regional Law No. 47/92 and the Avalanche Hazard Location Map, aim to mitigate avalanche risk by regulating land use in vulnerable areas.

The methodology developed in this article focuses on the construction of static and dynamic risk scenarios using user-friendly data, contributing to a wider multi-risk analysis framework. Furthermore, the work presented is aligned with the goals of the SICURA project, which aims to build risk scenarios within a global framework of smart security technologies.

Keywords: Avalanche risk · Urban planning · SICURA project · Accommodation facilities

1 Introduction

The transition from traditional agricultural toward service- and leisure-orientated societies, especially outdoor activities, encouraged population and tourist influx and led to socioeconomic activities development in mountainous areas. This shift is reflected by an increasing use of those areas for settlement, industry, and recreational service [1, 2].

The development of winter mountain tourism has historically interfered with avalanche activity and impacts on the mountain environment. The diversification of tourist activities, with particular reference to ski tourism, trekking, etc., has caused a significant intensification of anthropic elements in mountainous regions, resulting in an

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increased demand for facilities and infrastructure. All this represents an implicit issue for human safety relating to avalanche risk [3, 4].

In cases of scarcity of suitable areas for urban transformation, urban expansion in avalanche-prone area has occurred [2, 5]. This directly effects the level of exposure of settlements and the need to find new solutions to ensure the liveability of these places from a risk perspective [6]. Some studies have focused on the temporal evolution of avalanche risk caused by changes in exposure, for example the variation in the number of buildings was investigated in Davos (Switzerland) and Galtur (Austria) [2, 5], the demographic trend was considerate in Sakhalin Island (Russia) [7], while the evolution of the number of places in each alpine hut and refuge was analysed in Făgăraș Mountains (Romania) [3].

The territory of the Abruzzo region is predominantly mountainous (65%) [8]. While this results in a very high probability of being affected by avalanche phenomena, it also represents a great attraction for mountain tourism. The increasing in exposure, as a consequence of this trend, involves an increase in risk estimated as a combination of hazard, exposure and vulnerability [9].

This variability of avalanche risk linked to local changes in socio-economic and environmental drivers is an important factor to consider [10]. In particular, it should be noted that the climate change, with variations in temperature and snowfall properties, can modify the activity of the avalanche dynamics by altering the existing frequency–magnitude relationships for hazard scenarios [11]. Extreme events are increasingly frequent, strongly affecting slope stability and can generate avalanche movements [12, 13]. The result of increased avalanche risk levels is the occurrence of catastrophic events just as happened on 18 January 2017 in the municipality of Farindola (in the province of Pescara) where, as a result of heavy snowfalls, an avalanche hit the Hotel Rigopiano causing the death of 29 people and the total destruction of the structure [14, 15].

According to the Italian Civil Protection Agency, avalanches are defined as critical events caused by the sudden loss of stability of snow on a slope, followed by the sliding downhill of the portion of snowpack affected by the fracture. More in general, the risk is represented by the possibility that a natural or human-induced phenomenon, may cause harmful effects on the population, residential and productive settlements, and infrastructure within a particular area over a specific period of time. Within the framework of avalanche risk, the Regional Law No. 47/92 [16] regulates avalanche risk prevention activities by defining the Avalanche Hazard Location Map ("Avalanche Map" from now on), developed and approved by Regional Government Decree No. 559/21. This information allows the planning of transformations, assessing, among other things, the need for defence measures or regulating the development of new infrastructure and urban settlements.

The approach proposed in this article was developed as part of the PhD project carried out in collaboration with the Regional Civil Protection Agency (Abruzzo region) and concerning the analysis of spatial dynamics and local planning in the context of avalanche risk. The methodology built in this first phase concerns the development of dynamic risk scenarios related to avalanche phenomena, based on simple and user-friendly data. It is configured as a step in a multi-risk analysis that fits into the methodological framework proposed by the project "caSa Intelligente delle teCnologie per la sicURezza (Intelligent

Home of Security Technology)" – SICURA with regard to the construction of risk scenarios [17, 18].

2 Study Area

The study area covers the municipalities of the "Gran Sasso e Monti della Laga National Park" (PNGSML – EUAP0007) included in the Abruzzo region. The Park was established by the Law No. 394/91 "Framework Law on Protected Areas" and covers a territory of 1,500 square kilometres (sq km) in three regions of central Italy (Fig. 1). The 84.4% of the Park's area is located in the Abruzzo region, 9.10% in the Lazio region, and 6.5% in the Marche region.

The area of the Gran Sasso e Monti della Laga National Park ("National Park" from now on), involves a total of 44 municipalities including 40 Abruzzo municipalities whose administrative boundaries are, in some cases, totally inside to the park, while in other cases are only partially included (Fig. 2).

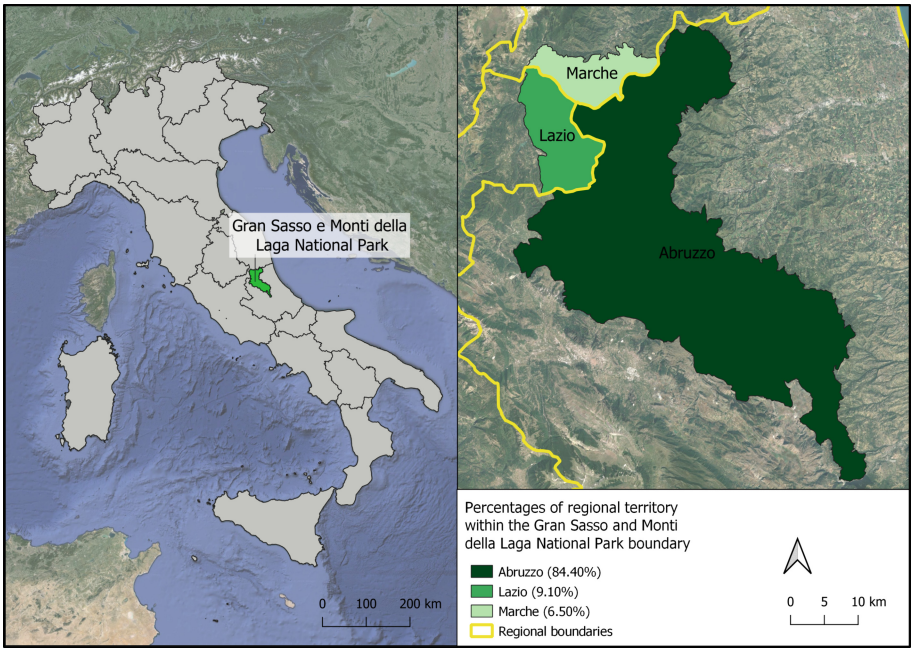

Fig. 1. Territorial framework. Italy and regional boundaries (on the left); Gran Sasso e Monti della Laga National Park with reference to regional boundaries.

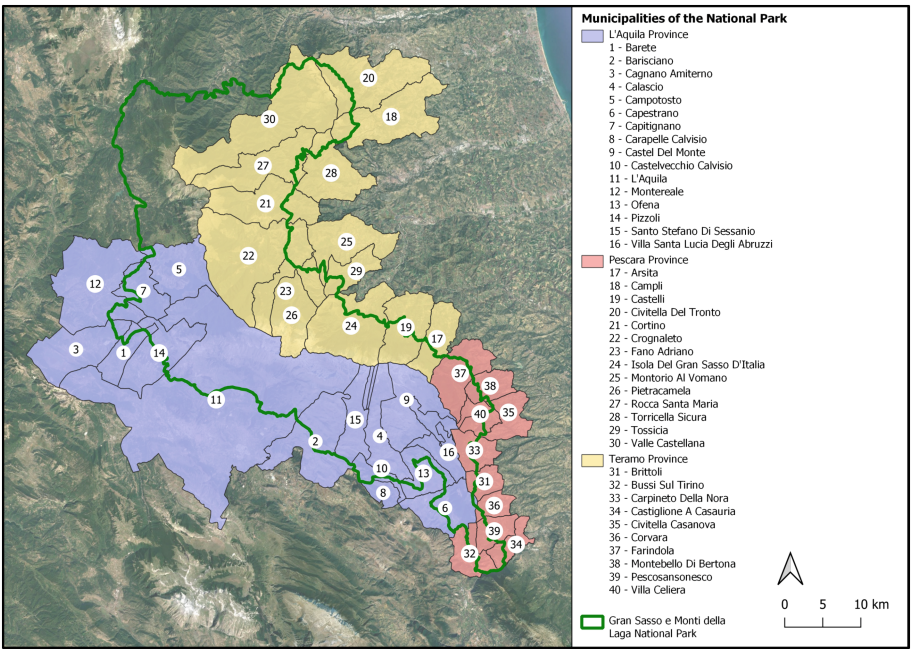

Fig. 2. Municipalities included in the National Park of Gran Sasso and Monti della Laga. The three provinces are represented with different colours. Among the 40 municipalities involved, some are totally internal to the park while others are included only in part.

The population density (inhabitants per square kilometer) is calculated from the data of resident population, updated to 1 January 2023, extracted from the database of the National Institute of Statistics (ISTAT [19]). The density population value ranges from a minimum of 3.1 inhabitants per square kilometer for the municipality of Calascio to a maximum of 616.3 inhabitants per square kilometer for the municipality of L'Aquila.

The territory of the National Park is mainly mountainous and most of urban settlements are developed in valleys and flat areas. The distribution of urbanized areas, therefore, reflects the topographical characteristics of this area. Considering the urbanizing area only as the buildings area extracted from the National Dataset of Structural Aggregates provided by the Regional Civil Protection Agency, it is possible to evaluate the urbanization density index for the portion of the territory of municipalities inside the park. It assumes the highest values for the municipality of L'Aquila, while the lowest one is recorded for the municipality of Barisciano.

3 Materials and Methods

One part of the SICURA project, focuses attention on integrating technological and methodological innovations into spatial planning tools to preserve the socio-economic framework of the territory under consideration.

Specifically, the project addresses urban and spatial resilience in response to climate change and risk conditions, with the aim of moving from static to dynamic spatial risk scenarios.

A static risk scenario concerns the vulnerability of populations or structures, based on their residence and geographic location, as documented [20]. In contrast, a dynamic risk scenario must consider population movement patterns to assess potential risks in particular areas at specific times of day [21].

In the building of these scenarios, we consider factors such as population flows and infrastructure exposure, using a framework that includes six main assets: urban, ecosystem, risk, urban planning, socioeconomic, and policies related to urban strategy [18].

The methodology of this article focuses on the analysis of avalanche risk related to the location of accommodation facilities in the territories of the municipalities within the National Park. A preliminary static risk scenario is evaluated by a density map related to the location of accommodation facilities. The dynamic preliminary risk scenario, on the other hand, is assessed by a density map related to the location of accommodation facilities weighted by the number of beds in each of them.

The overlay between the density map related to the dynamic scenario and the Avalanche Map allows the identification of the main analysis hotspots for the avalanche risk exposure factor.

3.1 Dataset

The data used for the analysis is about accommodation facilities and Avalanche Map.

The dataset of the accommodation facilities in the Abruzzo region for the year 2023 was provided by the Regional Civil Protection Agency. It contains information for each accommodation facilities about: i) the municipality of location; ii) type of structure (Hotels, Bed & Breakfasts, Campsites, Holiday homes, Country houses, Hostels, etc.); iii) star rating (1, 2, 3, 4 stars or undefined); iv) alphanumeric code associated with the structure; v) name; vi) address; vii) total number of bedrooms; viii) total number of beds; ix) total number of bathrooms.

The accommodation facilities were not directly associated with their geographic coordinates. For this reason, it was necessary to add geographic information in order to make the data comparable with other geographic layers useful for avalanche hazard exposure analyses. This was done automatically through GIS software with the use of the MMQGIS plugin [22] that allows to convert addresses to geographic coordinates. In this way the database was transformed into point shapefile data.

According to the Regional Government Decree No. 559/21, the Avalanche Map (Fig. 3), is not a risk map because it does not give indications about the frequency and intensity of phenomena or predictions of future events. It only reports the phenomena occurring up to the time of its drafting and represents avalanche sites and not individual

avalanches. There is currently no avalanche risk mapping for the Abruzzo region, but only the indication of the localization of avalanche-prone sites through the Avalanche Map is available. Information on the avalanche hazard level is provided daily by the MeteoMont Service [23] on a synoptic scale, taking into account the snowpack stability conditions at survey points and forecasted weather conditions.

Elaboration is divided into two successive phases, the interpretation of aerial photographs of the study area and subsequent direct investigation on the ground. Each avalanche, identified with a progressive numbering at the municipal scale, is associated with a technical report containing topographic information (slope and aspect of the avalanche site), vegetation details, frequency of the phenomenon, presence or absence of defence works, and any damages caused.

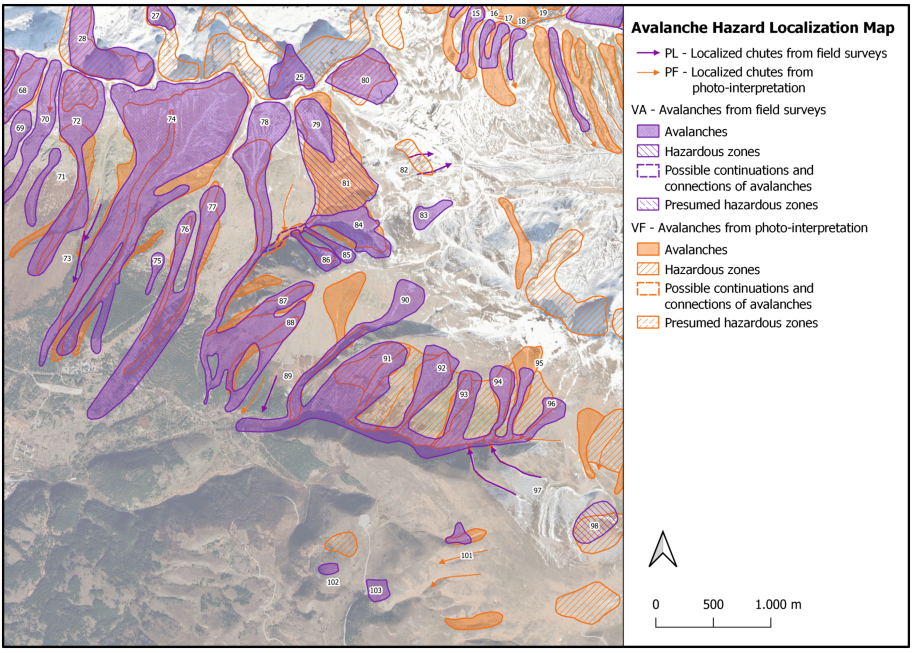

Fig. 3. General visualization of the Avalanche Map with its characteristic elements. Each avalanche is identified with a progressive numbering at municipal scale associated with a technical report.

In Fig. 3 the avalanches, hazardous zones and localized chutes are represented in purple if detected through field surveys, and in orange if detected through aerial photointerpretation. Each avalanche phenomenon observed on the ground is represented with reference to the maximum dimensions historically reached. In case the avalanche has expanded in the runout zone following different directions during different events, it is mapped the envelope of the maximum limits reached. The size of the avalanche site area is not modified based on the presence of defence works.

3.2 Validation and Density Map

The validation process is necessary to check and correct any errors in the geo-localization of accommodation facilities after their transformation into geographic data using the "MMQGIS" plugin.

A manual correction of the erroneous results generated by automatic geo-localization was carried out. The accurate location of the accommodation has been achieved through the support of geographic internet services (Google Maps [24]), digital travel assistance services (ViaMichelin [25]), tourism-dedicated websites (Abruzzo Turismo [26]), and other search engines (Microsoft Bing [27]). With the simultaneous use of these sources, it was possible to check and, if necessary, correct location of each individual accommodation facility and validate or make corrections to the database. Additionally, the database was integrated with information regarding any criticalities found (such as overlapping of different accommodation point features, facility status or name, incorrect or incomplete address from the original dataset, etc.).

The density maps were generated to perform a territorial analysis of the presence of accommodation facilities within the municipalities of the National Park. The heatmap plugin, available on QGIS, uses Kernel Density Estimation to create a density (heatmap) raster from an input point vector layer. Each pixel of the raster map corresponds to a different density value depending on the type of information analysed.

A preliminary risk scenario is evaluated by two density maps related to the location of accommodation facilities and the number of beds. The density maps were generated considering: (a) the locations of accommodation facilities; (b) the locations of accommodation facilities with weights based on the number of beds available for each of that.

The following characteristics were considered a pixel size of 50x50 meters and a Kernel bandwidth of 10,000 m radius. The radius specifies the distance around a point at which the influence of the point is felt.

The density map (a) could be considered a static preliminary risk scenario since it is based only on the presence of the accommodation facility without considering its possible capacity and thus the presence of users.

The density map (b) could be considered a dynamic preliminary risk scenario since it is based on the presence of users in accommodation facilities.

The density maps obtained were overlaid with the Avalanche Map. This operation allowed highlighting the presence of people and accommodation facilities in avalanche-prone areas, thus providing a basis for future exposure and risk analysis. The information regarding the number of beds, directly correlated to the type of facility, can be interpreted as the accommodation capacity of the structure itself. Using this data, it will be possible to generate various risk scenarios by adjusting the exposure level according to the assumed occupancy percentage for the facility (maximum, half, etc.).

4 Results

The density maps (Fig. 4) related to the location of accommodation facilities and to the location of accommodation facilities weighted by the number of beds allow to evaluate respectively the static and the dynamic preliminary risk scenarios.

The first heatmap (a) reveals the highest density value for the city of L'Aquila, while significant density values are observed in the municipalities of Santo Stefano di Sessanio and Castel del Monte. The second heatmap (b), shows a different density values distribution. High values are found in the municipalities of L'Aquila, Santo Stefano di Sessanio, Pietracamela and Rocca Santa Maria. The highest value is recorded, obviously, for the city of L'Aquila as a result of the high number of accommodation facilities.

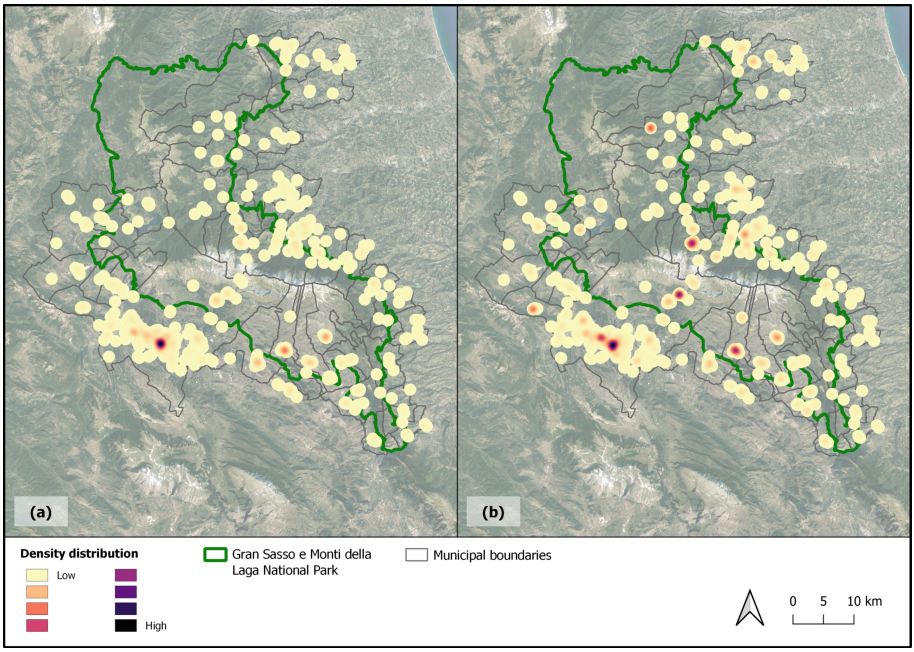

Fig. 4. Comparison between the density map based on the location of the accommodation facilities (a) and the density map based on the number of beds present in structures (b).

The dynamic scenario makes it possible to define an order of priority of the areas to consider as hotspots for the avalanche risk exposure factor and for which exposure and risk analyses are required.

Overlaying the density map (b) with the Avalanche Map, some criticalities are identified. In particular, the areas of Fonte Cerreto (L'Aquila) and Prati di Tivo (Pietracamela), located inside the National Park, are characterised by significant density values and certain avalanche phenomena (Fig. 5).

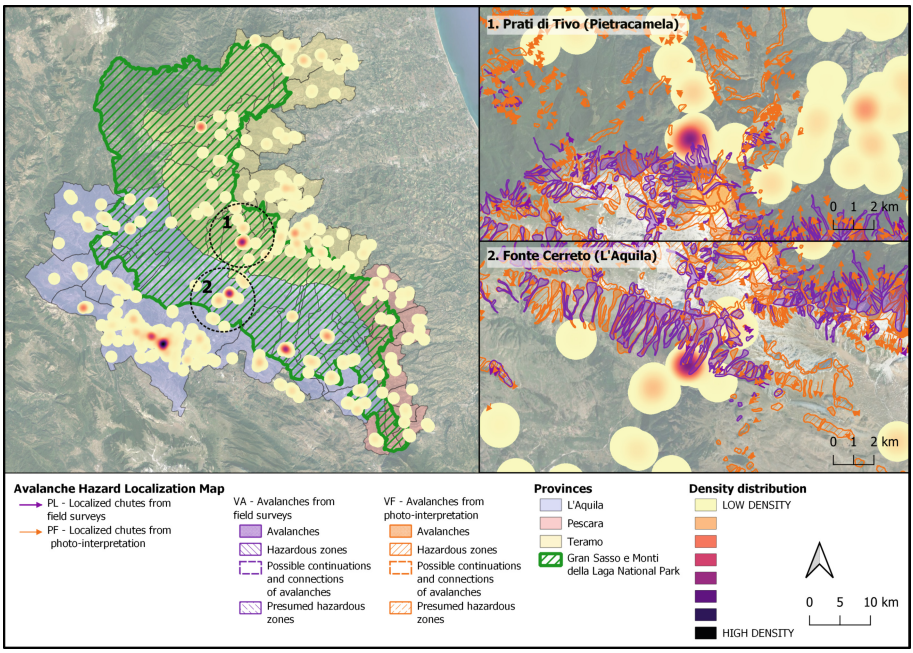

Fig. 5. Density map related to the location of accommodation facilities weighted by the number of beds and focus on critical avalanche prone areas of Prati di Tivo (Pietracamela) and Fonte Cerreto (L'Aquila).

5 Discussion and Conclusions

As part of this work, a preliminary analysis of the exposure of accommodation facilities in the municipalities of the Gran Sasso e Monti della Laga National Park was carried out, with particular reference to the avalanche hazard.

A static risk scenario, based on the location of the accommodation facilities in the territory, and a dynamic risk scenario, based on the accommodation capacity of the individual facilities, were built. The density maps obtained were overlayed with the Avalanche Hazard Location Map allowing the identification of critical areas with high levels of avalanche hazard and exposure, and the definition of an order of priority in the elaboration of future exposure and risk analyses for these hotspots.

In a risk analysis of a territory, it is essential to know the hazard, exposure and vulnerability factors that contribute to the risk definition and also their dynamic properties that are often not considered. In fact, the traditional approach to the risk is a static one [4] i.e. it does not consider the population flows that frequent places for reason different than residence. Variation in the intensity and frequency of natural hazards also as a consequence of climate change [11–13], together with changing in socio-economic conditions and settlement patterns induce variations in the level of risk to societies. Therefore, the spatio-temporal variability of risk factors is essential for a sustainable risk management [11].

This work covered the 40 municipalities in the Abruzzo region of the Gran Sasso and Monti della Laga National Park. The vulnerability of this territory is partly represented by the significant natural heritage of the Natural Park.

In fact, as other mountainous areas, it has been affected, over the years, by an intensification of the anthropic presence as a consequence of a society increasingly oriented towards the development of recreational and tourist services that affect the spatial planning of these areas. In response to the growing demand for facilities and infrastructure, urban development has often taken place within areas at risk, with a consequent increase in the exposure of the facilities themselves and of the people accommodated [2, 4, 5]. For winter tourism, the main natural hazard in mountain areas is snow avalanches, caused by the loss of stability of the snowpack on a slope.

The proposed methodology has been applied to the avalanche risk, however, for territories, such as the Abruzzo region, characterised by multiple hazards (hydrogeological, hydraulic and seismic hazard, landslides, etc.), a multi-risk analysis is needed. For this reason, the activity carried out with the SICURA project is fundamental to the collection of big data and the implementation of exposure and risk analyses through the development of 5G technology, focused on the security of infrastructures, environment, and cities. This is achieved through the use of solutions based on the Internet of Things (IoT) and artificial intelligence (AI), with a focus on cyber security [17, 18]. Through the collection of these data, it is possible to carry out multi-risk analyses and build different exposure scenarios in relation to the variation of tourist flows and the impact of climate change on the hazard of an area [28, 29]. Saving human lives is always the main objective for risk reduction and mitigation. In this context, the aim of this work is also directly related to the "Global Goals of the 2030 Agenda for Sustainable Development", and in particular to the following Goals: 3 – Good Health and Well-being, in relation to fighting mortality; 11 - Sustainable Cities and Communities, for the safety, sustainability and resilience of urban systems; 13 - Climate Action, for combating climate change; and 15 - Life on Land, for preventing deforestation and safeguarding ecosystems [30].

The preliminary elaborations, carried out in this study, provided results that can be used as input data in more in-depth analysis of the exposure in avalanche-prone areas. In the context of the goal of the PhD project, this methodology is useful as a first step to analyze the degree of interference between human settlements and avalanche sites and then develop a map of risk levels by combining information on land vulnerability and the avalanche hazard levels. The preliminary methodology presented is replicable since it uses simple available data. Moreover, it results in a decision support system for policy makers to act and plan transformation even in the most vulnerable areas such as natural parks and other protected areas.

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Authors Contributions. Conceptualization Lucia Saganeiti (LS) and Lorena Fiorini (LF); formal analysis Sara Pietrangeli (SP) and Donatella Guisa (DG); investigation SP; methodology LS, LF, SP; supervision LS; validation LF and LS; writing original draft LS, SP, LF.

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Multidimensional Evolutionary Evaluations for Transformative Approaches (MEETA 2024)

A Data-Driven Approach to Monitor Sustainable Development Transition in Italian Regions Through SDG 11 Indicators

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Abstract. Monitoring SDG 11 targets is crucial for making informed decisions and supporting multidimensional transitions in European cities. Among all the goals, SDG 11 emerges as a cornerstone for cities, offering a comprehensive framework to tackle their multifaceted challenges. Composite indicators and indices, as suited evaluation tools to monitor city progress or decline, allow sustainability problems to be included in local agendas by aggregating multi-dimensional variables at different time spans through data-driven approaches. The primary concerns about using indicators as evaluation tools to compare performances are inherent to inconsistencies related to different assessment frameworks and methods, data downscaling from global to local levels, choice of aggregation rules to obtain synthetic results, and data gaps. This contribution, in particular, focuses on data gaps by elaborating on a testing case, while critically discussing related issues. The research was addressed to identify normative, assessment, and methodological gaps in monitoring progress towards SDG 11 at global, European, and Italian levels. Application of Machine Learning algorithms to predict null values within an SDG 11 regional dataset was implemented to compare three Italian regions according to 18 common indicators. The contribution is part of the Research Project of National Relevance "GLOSSA - GLOcal knowledge System for Sustainability Assessment of urban projects", coordinated by Polytechnic of Turin (Italy), and it supports its first-step knowledge phase aimed at identifying gaps in SDG 11 indicators downscaling and monitoring.

Keywords: SDG 11 monitoring · Data-driven approach · Machine Learning · Indicators · Sustainable Development Strategies

1 Introduction

Among the 17 Sustainable Development Goals (SDGs), SDG 11 emerges as a cornerstone for cities, offering a comprehensive framework to tackle their multifaceted challenges [1]. Fostering inclusivity, resilience, and sustainability, its targets should unfold the city's potential to be more vibrant in social-cultural terms, resilient, and economically equitable [2]. Monitoring SDG 11 progress is, thus, crucial for making informed decisions and supporting multidimensional transitions in European cities [3].

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Indicators, in their single or composite form, constitute suited evaluation tools to monitor city progress or decline since they allow sustainability problems to be included in local agendas by aggregating multi-dimensional variables at different timespans [4, 5]. Furthermore, these metrics can be incorporated into diverse models to elucidate current patterns or to simulate and forecast potential outcomes under varying conditions, envisioning future iterations of urban landscapes [6].

Data-driven approaches provide a robust framework for measuring, analysing, and interpreting various phenomena through indicators [7]. By harnessing the power of data, these approaches offer insights into trends, patterns, and correlations that enable informed decision-making across diverse domains. Moreover, they facilitate the analysis of indicators through advanced techniques such as statistical modeling, machine learning, and data visualisation, in order to uncover hidden relationships within the data, predict future trends, and derive actionable insights.

Among the various approaches, Exploratory Data Analysis (EDA) examines data from as many perspectives as possible, constantly on the lookout for identifying recurring data patterns. The purpose is discovering evidence about the data, and it is neither motivated by a need to confirm the existence of a specific impact nor is it backed by a statistical model that includes a mathematical formulation for such an effect [8]. Furthermore, EDA plays a propaedeutic role in preparing data for Machine Learning algorithms by providing fast insights into data characteristics, identifying data validation strategies, guiding feature selection, and using data visualisation to better represent the shape of the dataset [9].

The primary concerns about using indicators as evaluation tools to compare performances are inherent to: inconsistencies related to different assessment frameworks and methods, data downscaling from global to local levels, choice of aggregation rules to obtain synthetic results, and data gaps [10]. This contribution focuses on data gaps by elaborating on a testing case, while critically discussing related issues.

One of the main gaps in monitoring and forecasting indicators concerns data absence since it prevents downscaling at local levels. On the counterpart, the data gap can unlock indicators research in selecting consistent and context-aware proxy variables by integrating the bottom-up with the top-down dimension [11, 12]. Bridging this gap is crucial in the context of SDG 11, whose monitoring and evaluation require comprehensive data at both the macro and micro levels to understand urban dynamics, assess progress, and inform policy interventions. By addressing data gaps and adopting a data-driven approach, stakeholders can better track urban development indicators, identify disparities, and tailor strategies to promote equitable and sustainable urbanisation [13].

The research was addressed to identify normative, assessment, and methodological gaps in monitoring progress towards SDG 11 at global, European, and Italian levels. Application of Machine Learning algorithms to predict null values within an SDG 11 regional dataset was implemented to compare three Italian Regions according to 18 common indicators.

The contribution is part of the Research Project of National Relevance, coordinated by Polytechnic of Turin (Italy), referred to as “GLOSSA - GLOcal knowledge System for Sustainability Assessment of urban projects”, and it supports the preliminary knowledge phase aimed at identifying gaps in the SDG 11 indicators downscaling and monitoring.

2 Research Design

The research design was conceptualised to provide insights for the Glossa project which aims to define a knowledge-system to support Decision Makers in the evaluation of urban transformation projects. Whilst, in this study, the authors have selected and processed data at the regional level, the efforts were addressed to detect and solve assessment gaps linked to lacking data which generally recur in indicators downscaling.

Figure 1 shows the workflow which stems from three Research Questions (RQ), as follows:

- RQ1. How has SDG 11 been implemented and monitored through indicators at the global, European and Italian levels?
- RQ2. Which are the most recurring indicators selected by the Italian Regions within the RSDSs?
- RQ3. Which limitations emerge from the scientific literature related to SDG 11 indicators assessment methods?
- Each RQ has been stressed by using different analysis methods and evaluation tools, according to three phases:
- Phase 1. Multilevel Governance Analysis has allowed normative gaps to emerge from a critical overview of the main documents and assessment framework at global and national levels.
- Phase 2. Frequency Analysis of the most recurring indicators within the Italian Regional Sustainable Development Strategies (RSDS) has allowed a common to 18 regions set of SDG 11 indicators to be selected.
- Phase 3. Literature Review of scientific publications from 2016 to 2024 has allowed the most used SDG 11 assessment methods to emerge to identify limitations and recurring data analysis gaps. Research protocols within databases Scopus and Web of Science have been implemented in this phase.

Results of the previous 3 phases highlighted the data gap as one of the most relevant issues, requiring a specific focus on the input methods to predict missing data records for specific indicators at different timespan. Thus, a further phase follows:

- Phase 4. Machine Learning has allowed feasible solutions to data gaps to emerge, along with limitations, while EDA was addressed to show the most correlated indicators within the three regional areas of the GLOSSA project. K-Nearest Neighbours (KNN) Machine Learning algorithm has been implemented through Python 3 to predict null values within the dataset.

The last phase results consist of correlation matrices and bivariate distributions of the most correlated indicators, obtained through EDA, and prediction accuracy index graphs, obtained through KNN.

2.1 Multilevel Governance Analysis About SDG 11 Indicators (Phase 1)

A comparative analysis has allowed us to examine indicators-based frameworks at different governance levels to detect recurring issues in monitoring cities' sustainability and define a common set of indicators for Italian regions.

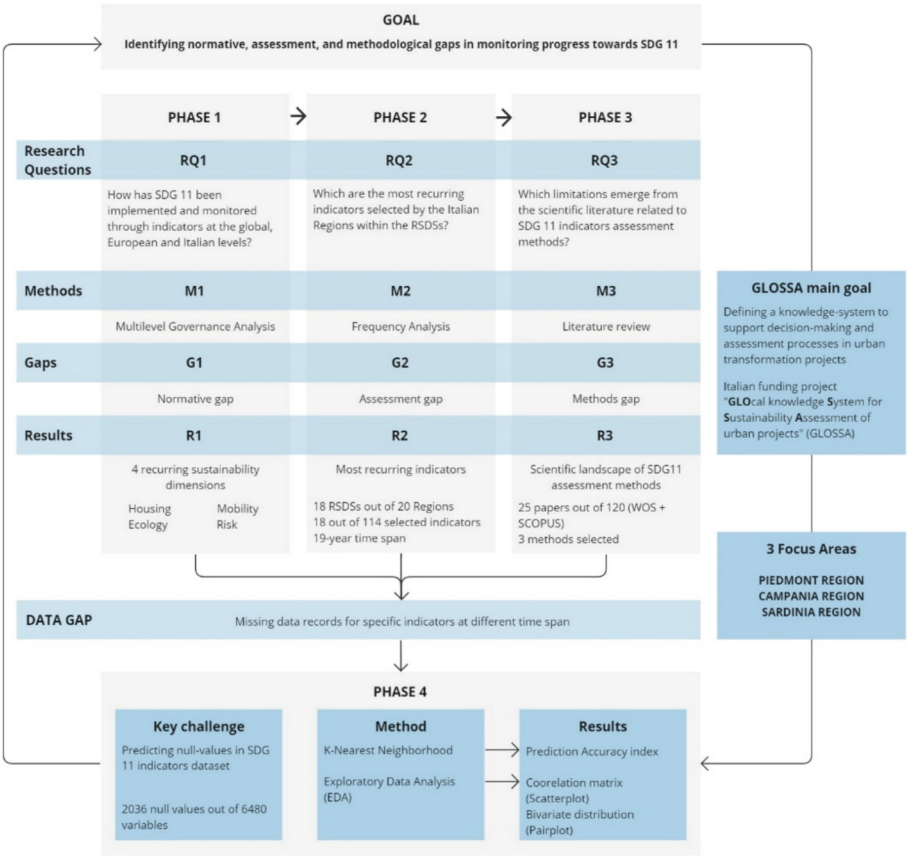

Fig. 1. Research design workflow.

With reference to the 17 SDGs of the 2030 Agenda and the corresponding 169 targets, the Statistical Commission of the United Nations established a shared framework of statistical information as a tool for monitoring and analysing sustainability. The activity programme of IAEG-SDGs includes, in addition to the implementation of indicators based on current methodologies and traditional data sources, the promotion and development of innovative elements that include non-traditional data sources, such as citizen-generated data, as complementary information sources. The current set proposed in 2023 by IAEG-SDGs consists of 231 indicators, although the total number considered is 248, as some are used for monitoring multiple targets.

At the European level, the European Commission (EC) put the SDGs at the center of its relevant governance tools such as the European Green Deal and the recovery and resilience plans under Next Generation EU.

Progress in achieving the SDGs is monitored by the European statistical office Eurostat through annual reports providing the assessment of short-term and long-term trends. The Eurostat indicator set does not directly address the 169 targets outlined in 2030

Agenda. Instead, it opted to choose suitable indicators that capture pertinent dimensions of the Sustainable Development Goals (SDGs) from the European Union's standpoint. Comprising 102 indicators distributed among the 17 SDGs, the EU indicator set allocates 6 dedicated indicators to each goal. Notably, 34 of these indicators serve the purpose of monitoring multiple SDGs simultaneously.

In the European context, member states are encouraged to develop appropriate policy and governance tools to establish national guidelines that facilitate the implementation of concrete actions at the territorial level to achieve and monitor the SDGs.

In Italy, the National Sustainable Development Strategy (NSDS) constitutes, since 2017, the reference framework for environmental and territorial planning, programming, and evaluation processes at all scales. This document reports a preliminary set of indicators, later implemented by ISTAT through the "Working Group for the definition of indicators for the National Strategy for Sustainable Development", established in 2018 with the convergence of the Ministry of Foreign Affairs and International Cooperation (MAECI), the Ministry of Economy and Finance (MEF), the Presidency of the Council, and the Higher Institute for Environmental Protection and Research (ISPRA). As of this, the first 43 indicators for the NSDS were selected, within the broader framework of ISTAT SDGs indicators. Since 2016, ISTAT has been making available numerous indicators on a semi-annual basis, many of which intersect with the Fair and Sustainable Well-being (BES) indicator system, encompassing a shared total of 62 statistical measures. In the sixth edition of the ISTAT Report on Development Objectives, an amount of 372 statistical measures are presented. Among these, 342 measures are distinct and linked to individual goals, correlating with 139 indicators outlined by the IAEG-SDGs to monitor worldwide advancement towards 2030 Agenda.

Another notable actor in SDGs monitoring is the Italian Alliance for Sustainable Development (ASviS). Since the consultations initiated by MASE in 2016 for the NSDS, ASviS has established an openly accessible web database containing 168 composite indicators aligned to UN indicators and designed to evaluate national advancement and setbacks concerning the SDGs.

The latest NSDS strategic framework comprises five areas aligned with the 2030 Agenda's five pillars. Additionally, it encompasses a sixth domain termed Sustainability Vectors, which refers to cross-cutting areas of intervention deemed essential for instigating, directing, administering, and overseeing sustainability efforts at the local level. The NSDS establishes sustainable development objectives, which are related to - yet not identical with - the SDGs. These objectives are distinguished by the interplay among various SDGs, as per the Nexus approach [14].

For each domain, National Strategic Choices (NSCs) are identified, which correspond to the missions and components of both EU and national cohesion policies. These NSCs are associated with National Sustainability Objectives (NSOs), which, in turn, are linked to "Target Values" shared by other strategies such as the PNRR or the 2030 Agenda.

The NSDS outlines a foundational set of 55 first-level indicators aligned with NSCs. These indicators are chosen based on their prevalence in key programming frameworks, including the PNRR, BES, Economic and Finance Document (DEF), Plan for Ecological Transition (PTE), and Partnership Agreement/Development Policies. Additionally, there exist 190 secondary indicators associated with NSOs. Together with the primary

indicators, these secondary indicators play a crucial role in the annual monitoring and reporting of the NSDS. While the NSDS does not present a specific set of indicators explicitly aimed at assessing the achievement of individual SDGs, it indirectly indicates which indicators, aligned with the SDGs, should be chosen for the monitoring system.

Drawing from a range of indicators selected by entities such as the UN, Eurostat, ISTAT, ASviS, and those inferred from the monitoring system of NSOs within the NSDS, one can discern various recurring and pertinent themes aimed at enhancing Goal 11 across different scales, as illustrated in Table 1.

Table 1. Number and typology of indicators in global, European, and Italian normative.

Legislation/ Organization	Governance level	Total number of indicators	Number of SDG 11 indicators	Key themes
ONU	Global	231	15	Governance; Risk; Ecology; Housing; Mobility
EUROSTAT	European	102	9	Housing; Risk; Mobility; Ecology
ISTAT	National / Regional	342	32	Ecology; Risk; Housing; Mobility; Climate Change; Governance
ASVIS	National / Regional	168	6	Mobility; Ecology; Housing
NSDS	National	245	16	Ecology; Governance; Mobility; Risk; Housing quality

Upon comparing the five analysed sets, four key dimensions emerge as critical for comprehending the concept of a sustainable city: Housing, Ecology, Mobility, and Risk.

Underlining the universal significance of ensuring decent and secure housing for all inhabitants, each source incorporates indicators about housing conditions, such as the percentage of the population residing in urban slums, informal settlements or substandard housing, as well as those living in dwellings afflicted by structural deficiencies, dampness, or overcrowding. Certain indicators, such as the incidence of urban green

areas in the urbanised area or the exceedance of daily thresholds for pollutants, underscore the imperative of sustainable management of natural resources and the urban environment. This entails advocating for sustainable consumption and production practices and enhancing the valorization of urban ecosystems. Numerous indicators, including the accessibility to public transport, passenger-km offered by public transport, and the prevalence of car usage for passenger transit, underscore the importance of fostering efficient and accessible public transportation infrastructure and services. Additionally, data highlights the necessity of implementing preventive and mitigation measures, as well as promoting safety and inclusivity within urban areas. This is evidenced by indicators such as the population exposed to landslide and flood risks and fatalities resulting from road accidents.

2.2 SDG 11 Indicators Within the Italian Regional Sustainable Development Strategy (Phase 2)

The NSDS - established as the national framework by Article 34 of Legislative Decree 152/2006 - provides for the formulation of strategies at the regional level to ensure monitoring of the contribution to the achievement of NSOs by territorial policies.

In this regard, regional and provincial administrations have established steering committees composed of internal administrative structures with competencies in social, economic, and environmental issues for sustainability monitoring. These entities, either through working groups or coordination boards, are engaged in the formulation of Regional Sustainable Development Strategies (RSDSs). In certain instances, the responsibility for coordination is directly assigned to the Regional Presidency or the General Secretariat.

Furthermore, numerous regions engage external entities, including provinces, associations, regional agencies, and other public or private organizations, to foster an integrated and participatory approach to urban sustainability. Moreover, by setting up Forums for Sustainable Development, coordination and monitoring efforts seek to engage a diversified range of stakeholders from the local community to boost RSDSs.

Within this intricate multi-level governance framework, there is a pressing need to establish an integrated monitoring system for the NSDS. The main effort involves identifying a common set of indicators, adaptable to different territorial levels, to gauge the contribution of regions towards NSDS implementation and SDG attainment.

While ASviS proposes a comprehensive set of 168 indicators to assess regions' performance in advancing the SDGs across various sectors, a unified national regulatory framework for such monitoring has yet to be defined. An analysis of the 17 RSDSs approved by MASE reveals significant variation in the indicators selection process among Italian regions due to the absence of a standardised tool. Some regions rely on the 44 indicators devised by the Working Group while others utilise indicators from ISTAT SDGs or the Fair and Sustainable Well-being (BES) framework. However, the majority of regions emphasise the selection of indicators based on local relevance and data availability, often integrating national indicators with regional or local ones.

Moreover, different approaches to monitoring progress in attaining the Sustainable Development Goals (SDGs) have been observed. While some regions have devised assessments that cut across their strategic initiatives, constructing composite indicators

to assess progress towards the SDGs, others have chosen to evaluate their strategic initiatives in alignment with the NSDS model. In this latter approach, regions prefer to assess their strategic initiatives using indicators linked to the SDGs, rather than directly measuring the achievement of individual Goals. Consequently, the evaluation is not focused on the achievement of the SDGs themselves but on assessing the appropriateness of actions concerning the SDGs' targets.

In the pursuit of identifying a potential set of shared indicators at the regional level, the research compares the indicators either explicitly stated or inferred from the RSDSs for monitoring SDG 11 (Fig. 2). Through an examination of the various datasets of indicators provided at the regional level, notable discrepancies emerge in the approach adopted by each region.

Many regions (such as Puglia, Abruzzo, Molise, Lazio, Friuli Venezia Giulia, Liguria, Piemonte, and Valle d'Aosta) stand out for their extensive use of indicators, surpassing the selected set of 17 indicators. These regions, characterised by high population densities and intricate urban challenges, decided to adopt a comprehensive and multifaceted approach to evaluating urban sustainability. Conversely, some regions have opted for a limited number of indicators, which could indicate a focus on key aspects or resource constraints for developing a comprehensive monitoring strategy. For instance, Umbria and Tuscany utilise 3 and 6 indicators respectively, suggesting a more targeted approach or a territorial context requiring less detailed analysis. Certain regions prioritise indicators from the ISTAT SDGs database (such as Campania, Puglia, Sardegna, Sicilia, Marche, and Lazio), potentially driven by a desire for national and international comparability as well as limited monitoring capabilities at the local level.

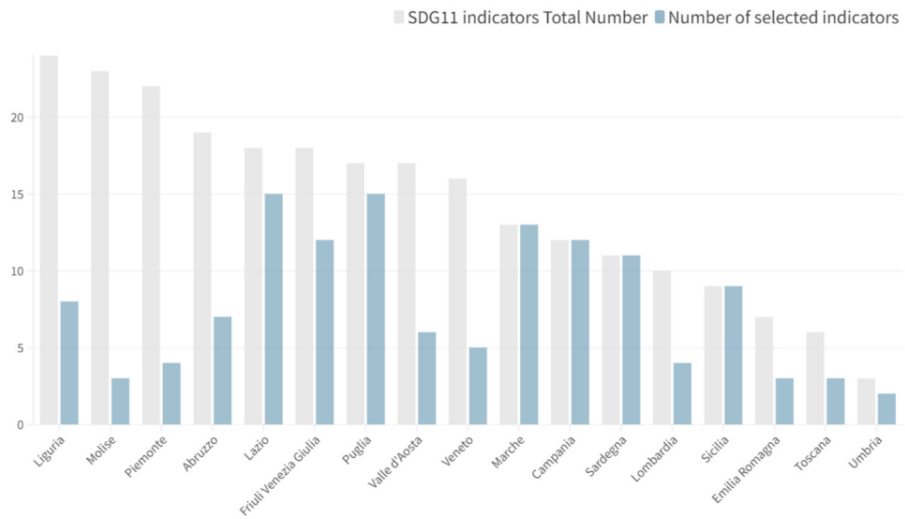

Fig. 2. Column chart of indicator frequency across Italian regions for SDG 11 assessment.

Similarly, other regions (including Abruzzo, Molise, Emilia Romagna, Friuli Venezia Giulia, Liguria, Piemonte, and Valle d'Aosta) favour territorial indicators developed at the local level. Collaboratively constructed with local authorities and territorial organizations, these indicators offer a more nuanced and context-specific perspective on urban sustainability. They may encompass data related to urban infrastructure, environmental quality, and community engagement.

2.3 The Scientific Landscape (Phase 3)

SDG 11, as is known, aims to make cities and human settlements inclusive, safe, resilient, and sustainable. Achieving this goal requires effective measurement and assessment frameworks to monitor progress and guide policy interventions at the regional level. Composite indicators, which integrate multiple indicators into a single metric, offer a comprehensive approach for assessing complex phenomena like urban sustainability. Statistical and multi-criteria methods play a crucial role in the construction of such composite indicators. This literature review critically evaluates the suitability of different statistical and multi-criteria methods for constructing composite indicators to assess SDG 11 in regional planning contexts.

The methodology involved a systematic literature review across academic databases, including Scopus and Web of Science, and using predefined keywords and logical operators as follows: "SDG 11" AND ("Composite indicator" OR "indicator" OR "indicator-based method" OR "aggregation method" OR "multicriteria decision analysis") AND ("sustainable development strategies" OR "regional planning" OR "policy" OR "scenarios assessment" OR "scenario planning" OR "scenario analysis"). The inclusion criteria encompass peer-reviewed articles, book chapters, and reviews published in the last decade, written in English, and focusing on the application of statistical and multi-criteria methods to effectively construct composite indicators for SDG 11 assessment in regional planning contexts.

25 relevant articles published between 2016 and 2024 were identified and screened for inclusion based on their relevance to the discussed topics and keywords. The results show that the most recurring research fields, according to WoS categories, are Environmental Sciences, Environmental Studies, Green Sustainable Science Technology and Urban Studies.

Through the network visualisation of the scientific landscape, as shown in Fig. 3, seven clusters related to composite indicators for SDG 11 assessment have been identified and referred to as: 1. Environmental footprint (red); 2. Energy and water management (green); 3. SDGs assessment (blue); 4. Network analysis (yellow); 5. Environmental management (purple); 6. Wellbeing (light blue); 7. WEFE nexus (orange). The weight of clusters indicates the number of term occurrences in the revised literature. It can be noted that the term "sustainability" clearly cuts across the clusters, which are characterised, on the one hand, with reference to the environment and natural resources and, on the other hand, in terms of assessment methods and sustainable management of resources, including a focus on the economic dimension.

Focusing on the sustainability assessment methods emerged from the revised literature, Multi-Criteria Decision Analysis (MCDA) provides several aggregation techniques, through compensatory, partially compensatory or non-compensatory approaches, to

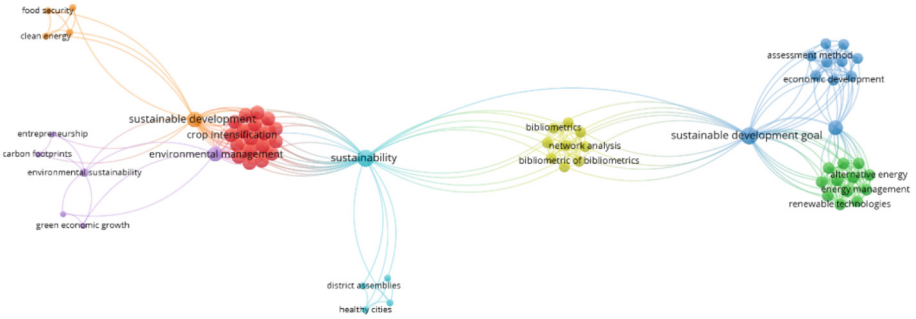

Fig. 3. The scientific landscape.

measure city progress towards SDGs [15]. Among different approaches, Ricciolini et al. (2022) suggest using Multiple Reference Point Weak-Strong Composite Indicators (MRP-WSCI) and its partially compensatory version (MRP-PCI) to incorporate indicator reference levels, enabling the use of both absolute and relative benchmarks. The advantage linked to the hybridisation of the two methods results in a composite indicator with varying degrees of compensation, which, on the one hand, empowers DMs to evaluate overall performance, on the other hand, to identify areas where improvement is possible [16].

Other assessment methods proposed by UN Inter-Agency and Expert Group on SDGs (IAEG-SDGs) Working Group on Geospatial Information highlight the geostatistical approach as crucial for harmonising indicators and enabling detailed SDGs evaluation at the most possible detailed geographical regions. According to this approach Benedek et al. (2021) compute an overall index to measure SDG progress locally and regionally in Romania using a proposed integrated approach with 90 indicators stored in a PostgreSQL database [17].

In Italy, the Italian Alliance for Sustainable Development (ASviS) has proposed a composite indicator for each of the 17 SDGs at the regional level using the Adjusted Mazziotta Pareto Index (AMPI), a methodology adopted by ISTAT to compare performances of administrative units over time and space [18]. AMPI is based on a mathematical function considering the arithmetic mean of normalised indicators, introducing a penalty for units with unbalanced indicator values, thus reflecting the multidimensionality of the phenomenon under consideration. ASviS chooses the indicator values - normalised to 100 - in 2010 as reference points to compare the regional performances for assessing progress towards SDGs.

Preliminary results from the literature review showed evidence supporting the feasibility of an integrated approach to policy evaluation through SDGs. Traditionally, such policies have primarily focused on economic metrics, while emerging research suggests a more holistic perspective, which considers economic, social, and environmental dimensions, offering a more nuanced understanding of effectiveness and broader societal implications.

3 Normative, Assessment, and Methodological Gaps

Three types of gaps in indicators-based assessments have emerged in answering the previous research questions concerning SDG11 monitoring framework from global to national level (RQ1), comparison of Italian Regions according to a standard set of indicators (RQ2), and methodological divergences and limitations in scientific literature (RQ3).

A significant concern is inherent to inconsistencies stemming from different assessment frameworks employed at different levels to monitor progress towards SDGs. Each framework, indeed, prioritises different urban dimensions, resulting in divergent conclusions even when analysing similar phenomena. While the four prevailing dimensions in sustainability assessment of cities - Housing, Ecology, Mobility, and Risk - recur in all the analysed frameworks at all governance levels, two infrequently selected dimensions emerge from the analysis of indicators, related to Governance and Climate Change.

Another challenge arises from the process of downscaling data from global to local levels. While global-level data offer a broad understanding of trends and patterns, its relevance and accuracy at local scales still remains compromised without guidelines and consistent criteria to validate indicators. Downscaling methodologies introduce errors or overlook critical nuances, leading to discrepancies in localised assessments. Consequently, decision-makers struggle to derive actionable insights tailored to specific geographical and social contexts.

On the other hand, the analysis of regional indicators highlighted a diversification of monitoring strategies for SDG11, influenced by territorial, economic, and socio-cultural factors. While some regions prioritise a broader and standardised perspective, others opt for a more targeted and contextualised approach, reflecting the complexity and diversity of urban and territorial challenges in Italy. These inconsistencies prevent DMs to cross-compare regions at a national level and, also, raise questions regarding the reliability of assessment outcomes.

Moreover, the choice of aggregation rules to obtain composite indicators poses another relevant gap. Aggregation methods vary in their complexity and assumptions, influencing the interpretation of the final measures. Decisions regarding aggregation favour certain perspectives or biases, potentially hindering important issues present in the underlying data. As a result, composite indices and indicators could oversimplify complex phenomena or fail to capture essential variations, limiting the comprehensiveness of evaluations.

Furthermore, the issue of missing data records for specific indicators at different time spans complicates the assessment process. Data gaps can arise due to incomplete data collection, methodological changes, resource constraints, monitoring lack in a certain time span. These gaps undermine the continuity of monitoring as well as introduce uncertainties in decision-making. The following Sections highlight possible solutions for setting a standard in the assessment of Italian Regions according to a common set of SDG 11 indicators and propose the use of ML to predict null-values in large datasets through the comparison of different methods.

4 Comparing Italian Regions Against SDG 11 Indicators: An Assessment Framework

A comparison of 17 Italian RSDSs has been performed to identify the most commonly adopted SDG 11 indicators. After determining the frequency of occurrence, indicators that appeared at least three times across the regional datasets were selected and presented in Table 2, thus ensuring a substantial representation of the issues addressed by Italian regions.

Table 2. The selected indicators framework.

Category	ID	Indicator	Source	Frequency	Polarity
Ecology	ECO_01	Incidence of urban green areas on the urbanised surface of cities	ISTAT	11	+
	ECO_02	Disposal of urban waste in landfills	ISPRA	9	−
	ECO_03	Soil sealing and land consumption per capita	ISTAT	7	−
	ECO_04	Urban air quality - PM10	ISTAT	7	−
	ECO_05	Air quality - PM2.5	ISTAT	6	−
	ECO_06	Urban air quality - Nitrogen dioxide	ISTAT	5	−
	ECO_07	Separate collection of urban waste	ISPRA	3	+
Housing	HOU_01	Percentage of people living in housing with structural problems or moisture problems	ISTAT	10	−
	HOU_02	Percentage of people living in overcrowded housing	ISTAT	10	−
	HOU_03	Building abuses	CRESME	10	−
	HOU_04	Percentage of people living in housing with noise from neighbours or the street	ISTAT	3	−
Mobility	MOB_01	Families reporting difficulty connecting with public transportation in the area where they reside	ISTAT	10	−
	MOB_02	People who routinely travel to work only by private means	ISTAT	8	−
	MOB_03	Students who habitually commute to study places only by public transport	ISTAT	7	+
	MOB_04	Passenger-km offered by public transport	ISTAT	5	+

(*continued*)

Table 2. (*continued*)

Category	ID	Indicator	Source	Frequency	Polarity
	MOB_05	Regular users of public transport	ISTAT	4	+
Risk	RISK_01	Population exposed to landslide risk	ISPRA	8	–
	RISK_02	Population exposed to flood risk	ISPRA	8	–

Hence, out of a total of 114 indicators, 18 were identified, with their frequency of use ranging from 3 to 11, of which only 3 had a value lower than 5. Regarding the sources, 5 indicators originate from ISPRA, 1 from CRESME, and the rest from ISTAT. Consistent with findings from the analysis of indicator sets provided by national and international agencies for monitoring SDG 11, the indicators chosen by the RSDSs encompass the four dimensions of urban sustainability previously defined.

Selected as the most frequent, these indicators shed light on various aspects of urban sustainability, facilitating a holistic and thorough evaluation of SDG11. The dataset is largely dominated by ecological and mobility indicators, reflecting the emphasis placed on environmental well-being and the imperative to mitigate detrimental emissions [19, 20]. Additionally, the significance of quality of life, defined as the right to reside in healthy and secure environments, is underscored across all RSDSs.

5 Results

The indicators were transferred into a bi-dimensional matrix through Python 3.0, where the sample refers to 19 years in the time span 2003–2022 and the features represent the indicator's values per region. The final matrix is, thus, shaped by 19 rows and 359 columns. The shaped matrix has approximately 2000 null values (NaN) corresponding to the third part of the total records. A mapping of the main statistics – e.g. mean, standard deviation, percentiles, frequency, etc. – has allowed exploring the overall dataset and single features related to indicators values per region.

5.1 A Predictive Model Based on the KNN ML Algorithm

KNN was used to predict null values in the dataset. The algorithm was set to select 2 similar points within known data representing a feature (column) of the dataset. Before implementing KNN, the matrix was split into training and testing data, hiding 50% of known values in the training data. An accuracy test was produced to check the consistency of the model comparing predicted values to hiding data. Several experimental tests have been performed to increase the model accuracy by changing parameters related to the number of K-points and the test size. Nevertheless, the accuracy test reached the limit of approximately 33% of correct predictions, as shown in Table 3.

Despite the low accuracy percentage highlighted a limitation of this study, it has been detected that KNN provide better results compared to filling dataset with zero or mean values. Further parameters changes can improve the accuracy level of the test, allowing for more consistent predictions.

Table 3. Accuracy test related to 4 imputation methods of null-values.

K-points	Test Size	Accuracy (%)
1	30%	16,0%
2	**50%**	**33,3%**
3	40%	1,5%
7	30%	0,0%

5.2 Exploratory Data Analysis (EDA)

An EDA was performed to derive the main statistics linked to the indicators set. Figures 4, 5 and 6 show the correlogram of all the regional indicators and the bivariate distribution of the most correlated variables. The correlation coefficients, being just more than 90%, provide strong insights into the relationships between the variables, indicating both the strength and direction of the relationships.

In the Campania region, it can be noticed that 'HOU_04' is negatively correlated with 'ECO_07' at 91%. Considering the divergent polarity of these indicators, it highlights that as the percentage of people living in housing with noise from neighbours or the street increases, the value of separate waste collection tends to decrease accordingly. 'MOB_04' is strongly positively correlated with 'ECO_02' at 94% and negatively correlated with 'ECO_07' at 93%. 'ECO_01' is strongly positively correlated with 'ECO_03' and negatively correlated with the PM2 aerosol loading ('ECO_05') at 91%.

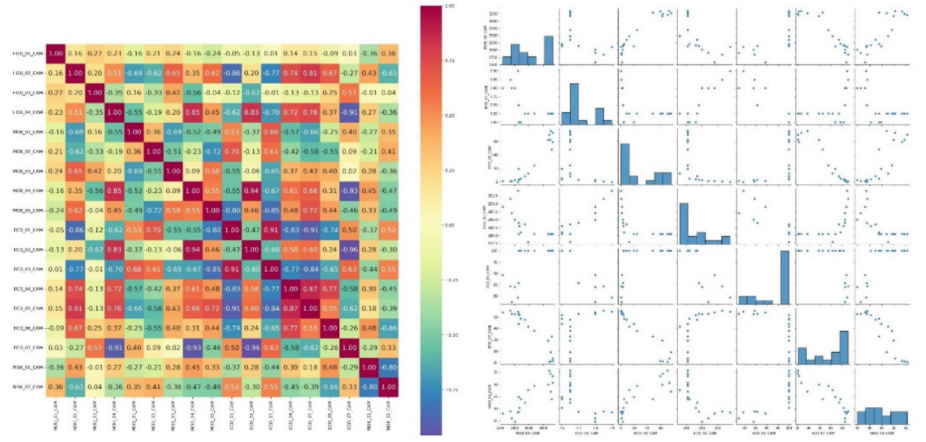

Fig. 4. The Campania region indicators correlation matrix (on the left) and a scatterplot of bivariate distribution (on the right).

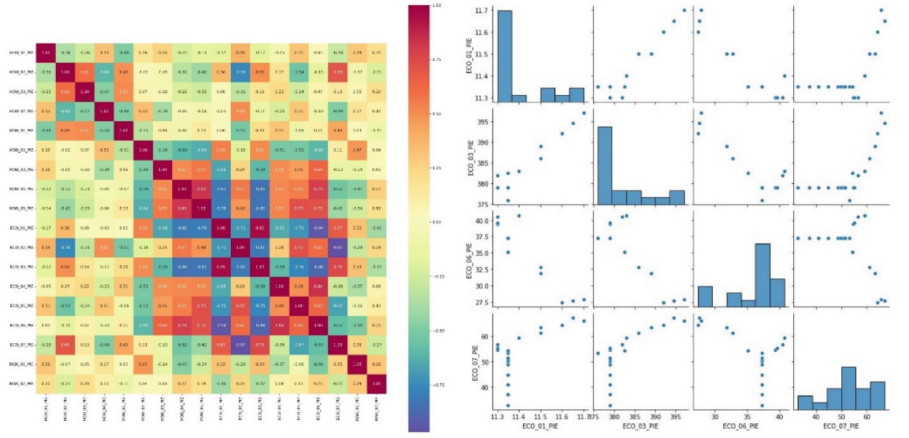

Fig. 5. The Piedmont region indicators correlation matrix (on the left) and a scatterplot of bivariate distribution (on the right).

In the Piedmont region, indicators 'ECO_01', 'ECO_03', 'ECO_06', and 'ECO_07' are the most correlated within the dataset. Specifically, 'ECO_01' is positively correlated with 'ECO_03' at 95% as for the Campania region, while a lower negative correlation level can be observed comparing both the variables with 'ECO_07'. Furthermore, indicator 'ECO_01' is strongly negatively correlated with 'ECO_06' at 94%.

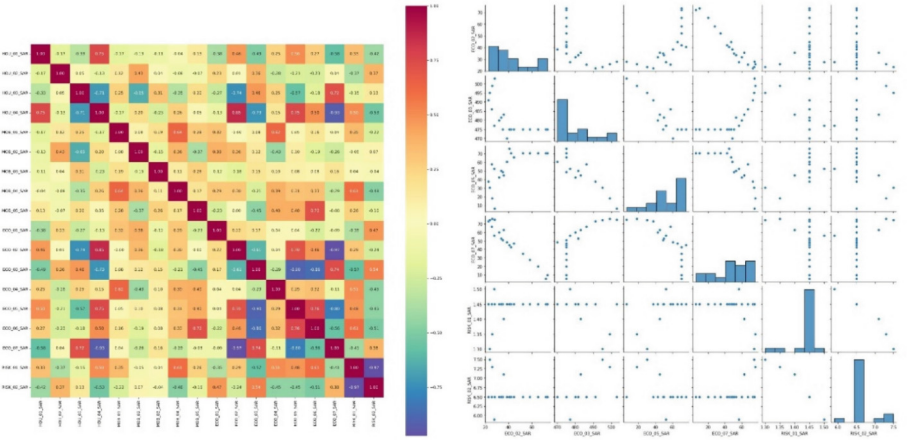

Fig. 6. The Sardinia region indicators correlation matrix (on the left) and a scatterplot of bivariate distribution (on the right).

In the Sardinia region, indicators 'ECO_07' and 'ECO_02' are strongly negatively correlated at 97%, as well as 'ECO_03' and 'ECO_05' at 90%. The indicators related to flooding 'RISK_01' and 'RISK_02' are negatively correlated as a decreased exposure to

landslide risk due to depopulation of inland areas is expected. Indicators 'ECO_07' and 'HOU_04' are also negatively correlated. Overall, no positive correlations above 90% are found.

6 Discussion and Conclusion

The contribution has proposed an assessment framework to compare Italian regions according to a common set of indicators, with the aim of identifying normative, assessment, and methodological gaps in monitoring progress towards SDG 11 at the global, European, and Italian levels. While Machine Learning has not completely solved the null values issues, it serves as a powerful tool to predict data and provide analysts with complete dataset to be manipulated. On the other hand, EDA sparks a data-supported interpretation of the most interrelated phenomena concerning urban sustainability.

Results of EDA conducted on the three mentioned Italian regions have provided some meaningful insights for interpreting the correlation between variables. In particular, it can be noticed from the Campania region correlogram that whether the correlation levels among these indicators could be spurious, it could suggest that as the passenger-km offered by public transport increases, the amount of urban waste in landfills tends to decrease, probably due to greater awareness of environmental sustainability or the availability and functioning of public transport. The incidence of urban green areas on the urbanised surface of cities positively affects the soil sealing and land consumption per capita as well as the air quality in the cities.

The results for the Piedmont region, instead, have shown high levels of positive correlation between the two above-mentioned ecological indicators respectively referred to as 'Incidence of urban green areas on the urbanised surface of cities' and 'Soil sealing and land consumption per capita'. These variables equally increase in the considered time span. It could depend on several factors, such as: data inconsistencies linked to low accuracy of KNN predictions, unbalanced development of detected green areas in different regional zones as well as spurious correlations between indicators. On the other hand, the negative correlation between urban green areas and the percentage of nitrogen dioxide is evident, nevertheless it can be further investigated by introducing a third variable concerning the incidence of free traffic zones that contribute to reducing pollutants. Thus, a deeper exploration of strongly correlated measures to improve environmental sustainability is needed.

Furthermore, the Sardegna region correlogram highlights specific phenomena to be interpreted: the decrease in the population living in areas exposed to noise pollution is related to the increase in separate collection. In fact, noise pollution in urban areas is often related to commercial and nightlife areas, with heavy vehicular traffic or nearby transportation infrastructure such as highways, railways, ports, airports or industrial areas. In these areas it can be more difficult to achieve high levels of separate collection. The decrease in urban waste in landfills, as can be expected, appears to be linked to an increase in separate collection. Moreover, the decrease in population exposed to landslide risk is linked to an increase in population exposed to flood risk. This phenomenon could be explained by a gradual migration of inhabitants from the more mountainous and landslide-exposed inland areas downstream and into the coastal areas more exposed to flood risk.

In conclusion, SDG 11 stands out as a pivotal framework for addressing the diverse challenges faced by cities, which progress monitoring cannot be underestimated, as it provides crucial insights for informed decision-making and supports multidimensional transitions within European cities.

Although it has been noted that indicators may be an inadequate tool for assessing progress toward SDG 11 at the global scale due to "a lack of benchmarks, targets, and explicit measurement of equity considerations" [21], this contribution provides evidence regarding the effectiveness of the proposed framework in performing comparative assessments at the regional level, due to the potential of using indicators not only as monitoring tools but also as evaluation standards for city planning to accelerate multidimensional transition, to detect from the comparison whether and how to act [22], and to push regions to confront not considering poor performance as punitive measures but rather as a spur to improvement in the rationale that "no one should be left behind".

Moreover, data-driven approaches, including Exploratory Data Analysis (EDA) and Machine Learning algorithms, offer robust frameworks for measuring, analyzing, and interpreting indicators, thereby empowering stakeholders to track urban development indicators and tailor strategies for equitable and sustainable urbanization [23].

However, challenges such as data gaps and inconsistencies in assessment frameworks persist, hindering effective monitoring of SDG 11 progress. Overcoming these gaps is essential and it requires a concerted effort to enhance the consistency, accuracy, and comprehensiveness of SDG 11 indicators-based assessments, which is one of the main goal of the GLOSSA project. Standardizing assessment frameworks and methodologies, improving data collection and sharing mechanisms, and employing robust validation techniques are crucial steps towards mitigating these issues.

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Assemblages for Cultural Heritage: A Methodological Approach of Heritage-Driven Enhancement

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Abstract. Cities are constantly evolving organisms where social, economic, and political changes challenge the design of new sustainable urban futures. In heritage-rich contexts, this often takes to the co-existence of transformation activities and cultural heritage, where culture plays an essential role in regulating human relations and shaping new infrastructures and organizational rules of our societies and urban ecosystems. In this perspective, a new approach balancing preservation and sustainable cultural value-based development is required. The paper analyses the UNESCO Historic Urban Landscape Recommendation approach as a holistic, integrative, and value-based approach. Nevertheless, the Recommendation needs to be implemented through a trans-disciplinary lens, aiming at the integration of knowledge to develop evaluation and policy models based on community-recognised heritage values. The research analyses the possibility of integrating an 'assembled' vision of urban ecosystems, co-constituted by 'human and non-human aspects', and the adoption of the Cultural Values Model as a tool to integrate diverse visions of cultural values of cultural landscapes, address rapid policy decisions, and ensure a sustainable future through heritage-driven actions.

Keyword: Historic Urban Landscape; · Quintuple Helix Model · Assemblage Theory · Cultural Values Model

1 Introduction

The today pressing global challenges have sparked the evolution of strategies aimed at fostering the concept of more sustainable, smarter, and greener urban centres. The city has been defined as a complex system, that can be compared to an entire living organism [1], whose initiatives have arisen amidst the backdrop of pervasive global socio-economic and environmental challenges that cities are facing. The urgency concerning implementing these strategies is demonstrated by the agenda adopted by the United Nations concerning the Sustainable Development Goals. As the notion of heritage continues to evolve, encompassing both tangible and intangible dimensions, it becomes crucial to re-evaluate its active role in shaping sustainable urban futures. This necessity is notably emphasized by Goal 11, "Sustainable Cities and Communities", which underlines the

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need to 'strengthen efforts to protect and safeguard the world's cultural and natural heritage'. Despite this passive and limited perspective, there is an opportunity to leverage heritage as a catalyst for sustainable urban development [2]. Building a concrete synergy between urban regeneration and cultural heritage has become a main topic in many European cities. Culture plays an essential role in regulating human relations, shaping institutions and organizational rules of our societies and urban ecosystem [3] and culture should be set as one of the main drivers of urban and economic up-growth [4].

When we talk about heritage-led urban regeneration, we are mostly directed to interventions in the conservation or reuse of abandoned or disused built heritage. Over time, European cities have developed several transformation interventions, which have meant a real boost to the local economy. It emerges in various studies how, unfortunately, ineffective these processes are in the long term if they do not adopt a participatory program integrated with environmental issues [5].

Special emphasis has to be placed on the possible effects that heritage values activate on regeneration projects and on the urban fabric in the generation of new functions, where functional, or adaptive reuse goes towards the transformation of a site in an integrated environmental vision, whereby, according to Fusco Girard [6] the site must be transformed into an ecosystem that can contribute to the vitality of the local context, involving in its essence and conformation, other subjects but also and above all groups of stakeholders participating in the activity of its management, possibly generating other ecosystems. In this sense, guiding sustainable urban transformation programs means having a greater and more comprehensive understanding of heritage roles and values in the urban environment.

Starting from this framework, the paper presented here attempts to define a link between the Historic Urban Landscape perspective, which has been adopted to facilitate the integration of heritage management and urban development, the Assemblage theory, made up of relations between natural elements and human artefacts, and the Quintuple Helix model theory, trying to outline an innovative approach that keeps the characteristics of the models and approaches presented within.

The article starts with an extensive introduction that opens up the theoretical framework of reference. In particular, in the first part, the HUL, the assemblage theory and the Quintuple Helix model are investigated, interconnected by an integrated and environmental heritage perspective. In the second part, the research focuses on the methodologies adopted, referring to innovative models concerning the holistic and integral characteristics of the cultural and urban landscape, regarding heritage-rich contexts. The adopted methodological approach introduces a conceptual framework that is open and sensitive to the dynamic characteristics of processes in societal ecosystems. As a case study, Hadrian's Wall, in the UK, will be analysed as an example of a cultural and natural ecosystem, reflecting the environmental, heritage and value characteristics analysed in the previous parts of the article. In the conclusions, it will be possible to establish some reference points for the developments that this research will potentially have later during its application and implementation in similar operative cases.

1.1 Historic Urban Landscape: A *Landscape* Point of View

Cultural heritage, in its broader sense, comes to cities into their socio-territorial complexity as a *cultural landscape*, which is considered by communities as a living heritage consisting of practices and experiences on the territory. The use of the word *landscape* possesses a holistic vision that is indispensable for the prospects of sustainable development for cities, integrating heritage conservation within the broader context of urban governance and value assessment. Landscape represents, in fact, not only a physical entity but also a socio-cultural construct and a mental and subjective representation of the environment that changes in time and space [7]. Over time, the word landscape has become part of discourses that have transcended the urban dimension and ended up interpenetrating several disciplines, such as ecology and archaeology. Already in 1992, UNESCO recognised the cultural landscape as a heritage category, and the Faro Convention, better known as the European Landscape Convention [8], brought out the value of landscape as an interaction between natural and/or human factors, making the way for an integrated approach between governments and communities and extending its definition to the exceptional, the everyday and the deteriorated. The Convention for the Safeguarding of the Intangible Cultural Heritage, in 2003, adds that intangible heritage acts as a driver of cultural diversity and sustainable development, defining it not only as the set of tangible aspects of a place, but also of the practices and experiences accompanied by personal perceptions resulting from the relationship between communities and the environment. The Vienna Memorandum [9], adopted in 2005, emphasises the role and value of landscape as a fundamental resource for society, which is not simply limited to the visual aspect of the territory, but also encompasses its complexity and importance for local communities and the environment. In 2011, the UNESCO Recommendation on Historic Urban Landscape (HUL) was adopted to facilitate the integration of heritage management and urban development. This Recommendation promotes a landscape-based approach, in which the identification of values and vulnerabilities are essential factors in the elaboration of urban development policies [10]. The HUL concept goes beyond the idea of focusing exclusively on the historic city and instead considers the urban whole, including the territory in this new understanding as an urban ecosystem, interwoven with the surrounding urban, rural and ecological areas.

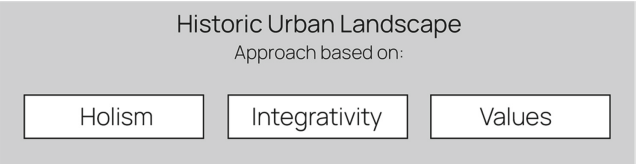

Fig. 1. The HUL Recommendation main points

Its first characteristic is holism [11], as physical-spatial, mental and functional aspects related to processes are taken into account. The second is integrativity, understood as interdisciplinarity, as it accommodates different perspectives between disciplines, including scientific and humanistic approaches as well as cultural and natural heritage

perspectives [12]. The third characteristic of this approach is that it is value-based, emphasising involvement and collaboration with communities associated with the landscape to understand the different values and meanings of heritage that could support a cross-cultural dialogue between different stakeholders regarding decisions on why a particular asset is of conservation interest [13]. Through this reading, the landscape goes from being only a physical resource to an entity intrinsically linked to the culture and identity of local communities, requiring a global and participatory vision in its conservation and management. The specificity of the UNESCO Recommendation on Historic Urban Landscapes is that it combines complementary principles, concepts, approaches, and areas that had already been separately addressed and adopted in previous European and international recommendations, providing a practical proposal for the implementation of a value-based landscape approach to cultural heritage management. The greatest challenge lies in bringing all these features together, *assembling* its components and addressing cultural heritage values in explicit and unambiguous terms for sustainable urban development and policies.

1.2 Assemblages as Dynamic Processes for Urban Transformations

The field of critical urbanism, which essentially elucidates contemporary urbanization patterns and endeavours to combat inequality within cities [14] serves as a useful starting point, as it frames many approaches that share the objective of creating inclusive cities that prioritize citizenship and well-being for all residents, thus serving as a crucial theoretical framework for fostering social sustainability. Expanding upon this, assemblage urbanism, deriving from the 'urban assemblage' concept from French philosophers Gilles Deleuze and Félix Guattari in Anti-Edipus and its focus on desiring machines [15], is a critical perspective that spans empirical, methodological, and ontological dimensions and aims to integrate diverse elements, including human and non-human interactions, networks, and the creation of socio-material and socio-spatial organization within the urban environment. The English term *assemblage* is a translation of the original French *agencement*. An *assemblage/agencement* is composed of multiple, heterogeneous parts linked together to form a whole [16]. However, the translation runs the risk of losing certain peculiar meanings of *agencement*, particularly its implication of the organization that fosters agency. From objects, buildings, technology and infrastructures to nature and social networking data, everything has its active agency and is dynamically interwoven as a component of social life [17].What is particularly relevant about the concept of agency is that it helps in understanding and unpacking the complex dynamic urban transformation of heritage places and the interaction between heritage and social sustainability [18]. Following Lieto's approach [19], in this paper authors seek to understand how urban transformations behave as a process open to multiple practices that enact architectural and urban design as a socio-material assemblage that is realised through multi-scalar processes, which go from grouping places and temporalities, actors and objects, functions and values, aggregated around common tasks. As a dynamic process, heritage-driven regeneration thus takes on a systemic dimension that is open to uncertainty, instability and spontaneity, examining the socio-material and socio-spatial organisation within urban environments. This approach emphasises the urban heritage system, taking into account local contexts and the broader processes of global urbanisation.

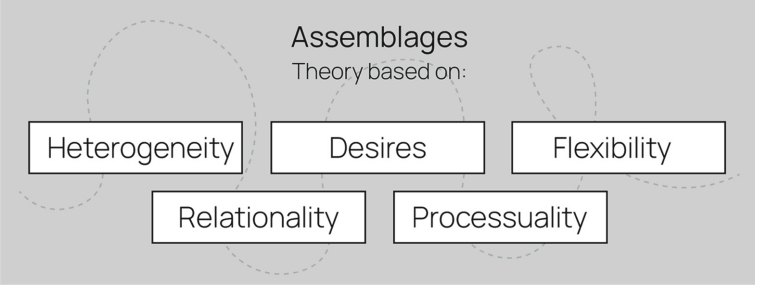

Fig. 2. The Assemblages main points

According to DeLanda [20] and as reported by Müller [16] assemblages are by their very nature 'fragmentary and fragmented' and have at least five specific characteristics that accomunise accompanies them: relationality, productivity, heterogeneity, deterritorialisation and desirability. The assemblage represents a whole that forms, through the connection of different units, a new whole, within which these connections represent relationships between people, objects, etc. These organisations reflect spatial and behavioural orders, new expressions of reality and new actors. The heterogeneity of such ensembles lies in the fact that, without assumptions, what is related escapes the nature-culture dimension [21] and unites humans, animals, things and ideas. Assemblages, as relations, hold together elements that, through their desire to mate, establish spatialities, which constantly change, transforming and breaking up the territories they stabilise.

1.3 The Quintuple Helix Innovation Model

An example of a societal ecosystem is the 'innovation ecosystem', which examines the complexity of innovation and innovation systems within the framework of societal and natural environments [22]. Non-linear models of innovation play a key role in their understanding. The concepts of biological and social ecosystems demonstrate the interdisciplinary breadth of ecology, illustrating the intellectual challenge of integrating ideas between the social and natural sciences while highlighting the benefits of interdisciplinary inquiry for transdisciplinary application.

The Quintuple Helix model (Fig. 2) developed by Carayannis and Campbell in 2010 [23], builds upon the Triple Helix and Quadruple Helix models to support eco-innovation processes and actions. While the Triple Helix emphasizes the interaction between academia, industry, and government in knowledge production and utilization, the Quadruple Helix includes the media-based and culture-based public as an additional helix. This integrated approach enhances the understanding and implementation of eco-innovation. The Quintuple Helix serves as an analytical framework for sustainable development and social ecology, facilitating the integration of societal ecosystems with social and natural environments [24]. Within an "innovation ecosystem", knowledge and learning are viewed as resources and processes, stimulating fresh ideas and opportunities, and nurturing creativity by inspiring "creative knowledge environments [25].

The Quintuple Helix model represents an interdisciplinary and transdisciplinary approach, necessitating a comprehensive analytical understanding spanning the entire disciplinary spectrum. This includes engagement with the natural sciences as well as with the social sciences and humanities to address societal, democratic, and economic aspects (Fig. 4).

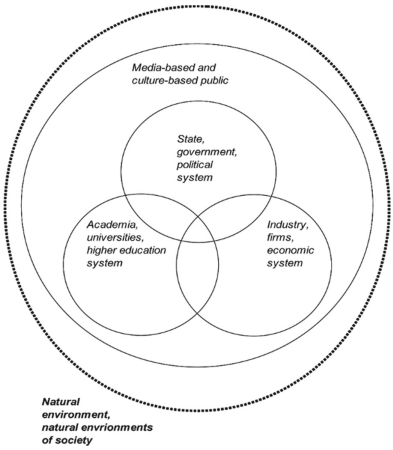

Fig. 3. The Quintuple Helix Innovation model by E. Carayannis and D. Campbell, 2010

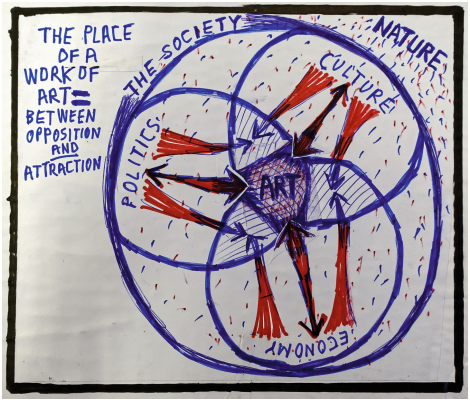

Fig. 4. Thomas Hirschhorn's schema titled "The place of a work of art", 2022

Moreover, the Quintuple Helix serves as a transdisciplinary framework for decision-making concerning knowledge, innovation, and the environment. Proposed as a framework for transdisciplinary and interdisciplinary analysis, the Quintuple Helix encompasses sustainable development and social ecology. By introducing the "fifth helix" of the natural environment to knowledge creation, production, application, diffusion, and use, it transforms knowledge and innovation systems into ones sensitive to social ecology. This conceptual framework enables the examination of how knowledge and innovation,

contextualized by society, intersect with environmental contexts, thereby facilitating sustainable development and social ecology analyses. Additionally, the model delineates the implications of sustainable development for eco-innovation and eco-entrepreneurship, offering insights into their roles in both the present and future contexts [23]. As already outlined by Carayannis and Campbell through the Quintuple Helix model (Fig. 1) 'sustainable development and social ecology represent areas and fields for interdisciplinary analysis and transdisciplinary problem-solving'. The interactions between human society, which is characterised by culture, and the material world, which is composed of the biophysical or nature, generate mutual knowledge. As shown in Figs. 2 and 3, the similarities between the scheme proposed by the visual artist T. Hischhorn (2022) and the Quintuple Helix model are extremely fascinating. A social ecosystemic vision emerges from both, where innovation, which in the field of art translates as 'the work of art', is positioned at the intersection of the political, cultural and economic sub-systems, which nourish each other by creating relational links (cross-referring and cross-relating ideas linking the social sciences to the natural sciences). Furthermore, flows emerge from Hirschhorn's scheme to represent the relationships that intervene and manifest themselves at the edges of subsystems. Their indication with a directionality suggests their relational and attractive power, that is, the influence - or agentivity - that each dimension has on the others. The artist, in this case, informs us of a dynamic ecosystem, within which forces manifest themselves by developing an environment that resembles Deleuze's assemblage, within which relationships of desire and attraction are created, new organisations and accorplations are produced, as well as distances and conflicts. Within these assemblages, confines become labile and constantly mutable.

2 Materials and Methods

2.1 Heritage Values Assessment Approaches

Over the last 150 years, heritage has been perceived and valued in many different ways. Cultural heritage is recognized for its value as a resource for human development and, as emerged from the World Commission on Culture and Development in 1996, as part of sustainable development key drivers. From heritage, important benefits can be gained, as well as important socio-economic functions in contemporary society, like the idea that heritage brings itself a public value expressed through the realm of the democratic realm [26]. As outlined in the Burra Charter (Australia ICOMOS, 1999), heritage defines cultural significance for its 'aesthetic, historic, scientific, or social value for the past, present, or future generations'. This definition of heritage values takes in different important considerations about heritage values that should be considered when talking about urban sustainable development in heritage-rich contexts. On one hand, designers, conservators and decision-makers should deal with the historical values associated with a site, and sometimes some scientific or archaeological values are embedded in it. The set of anthropocentric instrumental and intrinsic values represents a further tool and argument for heritage preservation. By recognizing both an instrumental and an intrinsic value to certain assets or resources, we can better justify heritage conservation and care than with only an economic or instrumental approach [6]. The use of heritage for modern erosive processes is shaping the contours of new geography which fights the mere use

of territories for tourism goals [27]. On the other hand, the function and use of heritage should be strongly connected to its contemporary social value, which is shaped by the social context and processes [13, 28].

Like all entities involving social activities, also heritage should not be considered as a static set of fixed meanings and objects, as suggested by traditional notions of intrinsic value and authenticity, but rather a fluid phenomenon that changes over time and varies from generation to generation [29]. Heritage value should be recognized for its value of legacy and bequest over time, but also as a long-term evolutionary process, like urban ecosystems because its value has been produced/created/recognized by people over a very long history [6]. In each moment, a given heritage site, building, or object has several different values ascribed to it, so heritage is multivalent and logically suggests a pluralistic approach to value assessment. 'Value is formed in the nexus between ideas and things' [13].

Despite the attempts to include material and immaterial urban heritage dimensions, Fouseki et al. have underlined how, in practice, the Historic Urban Landscape Recommendation has largely been placed on 'materially' and 'visually' oriented actions, where adopted strategies mostly concern urban conservation to prevent and mitigate impacts on cultural and natural heritage [30]. The cultural landscape is therefore recognized as an interactive phenomenon, more specifically a spatial and political phenomenon rich in meanings. At the center of contemporary, interdisciplinary, and critical research on heritage lies the idea that it is a social construct, the result of specific social processes at a certain place and time [13]. The meaning of heritage cannot therefore be associated with something fixed, but rather as something extremely intertwined with every aspect of individuals' lives, says museologist Susan Pearce, as something that social groups explicitly or implicitly recognize as part of their self-definition. Whether it is works of art, buildings, or ethnographic artefacts, cultural and material culture products have different meanings and uses for different individuals and communities. The attribution of value is what gives meaning to objects and places, creating the concept of heritage.

From a methodological point of view, the assessment of heritage values is very hard, and these difficulties stem from diverse factors, such as the nature of heritage values (cultural, economic, political, aesthetic and others - some of which overlap with others), the ever-changing nature of values themselves, which are strongly shaped by contextual factors (such as social forces, economic opportunities and cultural trends), the conflict between some values, and the wide variety of methodologies and tools for assessing them [13, 28]. Too often, experts determine heritage significance based on a limited number of established criteria or apply the assessment through unidisciplinary means. As an alternative to this approach, this paper advocates a transdisciplinary approach to analysing and evaluating heritage values.

2.2 Heritage-Based Innovation Models

Among other aspects, it is important to underline that socio-cultural sustainability approaches consist of a hybrid set of hard-to-measure "soft indicators" and ambiguous terms and concepts such as governance, community, and culture [31]. Both tangible, such as physical patterns, and intangible, such as symbolic meanings and values are attributed to the places where we live, which are marked by distinctive characteristics

[32] as well as aspects related to expression and language, such as art, music, dance, etc. In this sense, according to Taylor (Fig. 5), sites and objects assume the position of place within the *cultural landscape* that surrounds them, and the meanings we attribute to them give rise to local identity and a sense of belonging for communities.

Returning to the holistic, integrative, and value-based approach of the HUL, future challenges in the field of heritage conservation derive from contexts, namely from the values and meanings that communities attribute to them. The HUL approach still represents a valid point of connection between the concept of the cultural landscape and the analysis of the system of values layered within it.

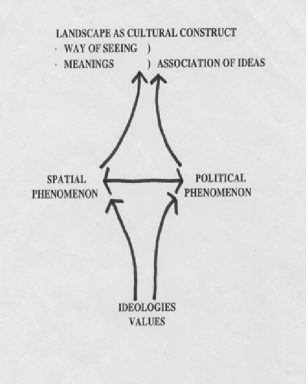

Fig. 5. K. Taylor's diagram for the concept of landscape as an interactive phenomenon.

The Recommendation specifically highlights the temporal dimension of the management of historic cities and their heritage, recognizing in the landscape approach an inspiring urban practice for the creation of democratic policies, which integrate the issue of heritage values within long-term urban planning. The approach presupposes an integrated – we could say *assembled* – environmental vision, which, referring to urban management approaches, opens up to a wider range of stakeholders, residents, investors, and experts. Consequently, heritage also expands its agency to a broader environment. In everyday language, the word 'environment' – as underlined in the previous paragraphs for the term 'landscape'- is normally associated with the natural environment, but its meaning is also commonly linked in the literature to the whole of societal subsystems. In a spatial-political multi-level architecture, societies could be located at different levels of aggregation - ranging from local to national and trans-national – and also being contextualized by the 'natural environment' [23]. Based on the interaction between living and non-living organisms, we define an 'ecosystem' as a sum of these relations. The concept of the ecosystem, originally rooted in the natural sciences, can be reimagined and adapted by the social sciences to form a 'social or societal ecosystem'. A societal ecosystem encompasses essential elements such as actors, institutions, structures, and processes, along with their intricate interaction patterns, mirroring those found in natural ecosystems. Moreover, it extends to encompass the contextualization provided by the social environments of other societal subsystems and is further contextualized by the

natural environment of the entire society. Societal ecosystems also have the potential to interact with both their social and natural environments.

Taking their cue from these representations in paragraph 1.3, the authors have developed a Quintuple Helix scheme that aims to generate a synthesis of these two approaches. The diagram represents the three subsystems which are education and academia, the political and governmental system, and the economic system. Following the model already outlined by Carayannis and Campbell, where at the intersection of the three sub-systems lies eco-innovation, the authors have included art as a generative innovation approach. The three systems are interconnected and, learning from the assemblage approach, outline continuous interrelationships between their elements. The civil system embraces the three sub-systems. In turn, the civil system is embedded in a natural and anthropic ecosystem, defined as the environment, which we could define as 'landscape', continuing the holistic approach outlined in the previous paragraphs. With the aim of restoring a framework of relationships, a new reinterpretation of the model of the Quintuple Helix is thus outlined, informed by the elements and relationships that constitute the assemblages (Fig. 6).

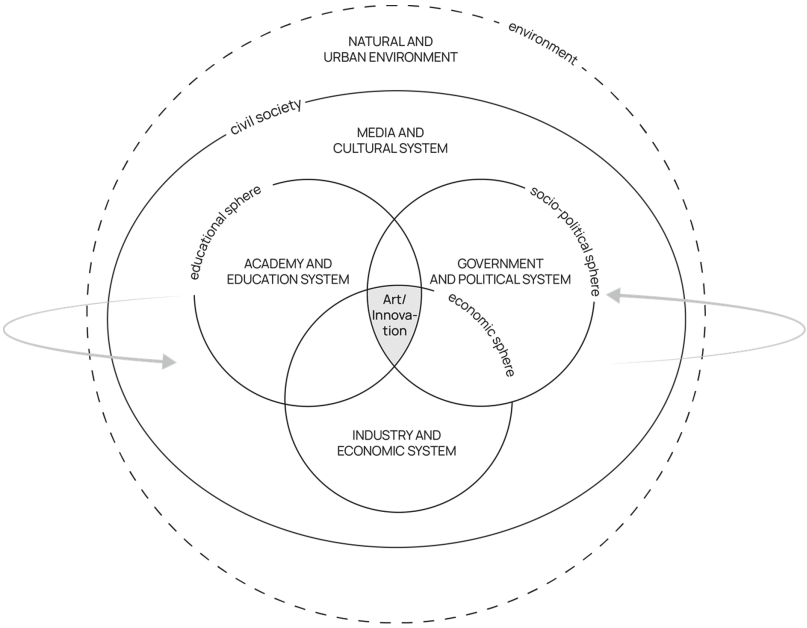

Fig. 6. Authors' elaboration which comes from the intersection between Thomas Hischhorn's schema in Fig. 2 ("The place of a work of art", 2022) and The Quintuple Helix model by E. Carayannis and D. Campbell, 2010, informed by assemblage theory.

2.3 The Cultural Values Model

The conservation community employs the term 'cultural significance' to encompass the various values attributed to objects, buildings, or landscapes, ranging from aesthetic to economic. Despite efforts to classify these values and promote value-driven conservation policy and management, there remains a gap in understanding how heritage functions within society and how cultural significance is best evaluated over time. Cultural significance in conservation decision-making cannot solely rely on scholarly constructs; instead, it requires negotiation among professionals, academics, and community members who value the object or place [13]. In evaluation, the explicit recognition of the existence of multiple interdependent values, which may sometimes even overlap with each other, allows us to include instrumental and intrinsic heritage values within the evaluation process. Intrinsic value allows us to go beyond the private sphere and reflect on collective benefits and externalities, making a clear ethical dimension explicit. It expresses the 'glue value', the intangible relationship system, its specific character, its particular identity. The recognition of values allows us to highlight different perspectives that can be of fundamental importance in the normative exercise related to a problem of public decision-making. These issues, therefore, are closely linked to decision-making processes, which strongly depend on the link between knowledge and values. When we talk about the recognition of values, we mean to reconnect to the multiplicity and diversity of knowledge. Already in 1999, McGlade proposed that the core issue lies in the "systematic fragmentation of individual specialist observations, which are subsequently 'incorporated' into a synthesized reconstruction of the cultural environment" [33]. Zeleny [34] speaks of the value complex as a concept anchored and deeply embedded in a cognitive equilibrium, based on mostly qualitative principles rooted in specific contexts.

The methodology presented here can be extremely supportive for decision-making processes concerning management and/or development strategies for heritage-rich sites. The recognition of the different values within the cultural landscape, but also of how these intertwine and mutually reinforce each other, is not unique. The Cultural Values Model seeks to discover what communities themselves value about their landscapes, to prevent decision-makers from relying exclusively on the version of 'landscape' proposed through the lens of the expert method or the canonical evaluation tools [35]. Thus, values that are not captured by these typologies may be ignored and therefore not legitimised. The methodological structure of the model adopts a participatory approach, which aims to offer insights that are less constrained by legal precedents or established valuation practices and more reflective of the actual cultural dynamics between communities and their landscapes. Drawing on contemporary landscape theories and holistic models, we can define some key points that define the structure and originality of the Cultural Value Model (CVM) for evaluation presents several challenges to conventional evaluation methods: abandoning traditional top-down metrics and the adoption of user-defined values; addressing the data collection methods to diverse stakeholder concerns; integrating the evaluation to the complete project design; approaching a participatory evaluation, which allows stakeholders to play a significant role in shaping processes and outcomes [36].

3 Case Study

3.1 Hadrian's Wall: An Eco-System of Values

Hadrian's Wall, in the UK, constitutes an archaeological resilience of great impact in English history, forming a whole with the surrounding landscape, since, if separated from it, the wall in itself loses meaning. In this sense, it represents a pertinent example of what we understand as both a natural and cultural ecosystem, where cultural heritage, in this case historical-archaeological, and the surrounding landscape are closely connected. The Wall constitutes an archaeological resource that, together with the surrounding landscape, is composed of economic, ecological, aesthetic, etc. values. The report published by the Getty Conservation Institute in Los Angeles constitutes a reference for the analysis of an emblematic case in the world of natural and cultural heritage, within which the values recognised by the experts can now, thanks to the established management model, be extended to the entire region. Recently, the archaeological sites and their socio-natural context have been the subject of an evaluation, contained in the aforementioned report, which has expanded the range of perceived values that have evolved and succeeded in this area over time. This has made it possible to adapt the management model of the archaeological sites, achieving a deeper understanding of the historical and cultural landscape, so richly stratified, bearer of narratives from different eras and places [37]. Such a territorially broad view requires an equally broad consideration of values (Table 1). The land is currently in active use and under the control of many distinct owners, but over time a non-exclusive approach to archaeology and historical value has settled in, which has allowed for a broadening of contemporary use values, allowing for complex and extensive landscape management.

Table 1. Hadrian's Wall values assessment: author's re-elaboration based on Getty Conservation Institute Report about Hadrian's Wall and site management plan (https://hadrianswallcountry.co.uk/management/values/, last accessed May 8, 2024).

Values Typologies	*Single values*	*Values significance*
Socio-cultural Values	*Historical and archaeological value (including academic/educational value)*	It represents the capacity of a site to transmit, embody or stimulate a relationship or reaction with the past (Roman Empire remains)
	Cultural/Symbolic Value	It refers to fundamental elements of culture, such as ideas, materials and customs handed down over time (identity as World Heritage Site)
	Social Value	It enables and facilitates social connections, networks and other relationships in a broad sense (promotion of management partnerships)

(*continued*)

Table 1. (*continued*)

Values Typologies	*Single values*	*Values significance*
	Aesthetic Value	It represents the visual appeal of heritage, encompassing notions of beauty and formal relationships, enriching the overall sensory experience of heritage and influencing individuals' well-being
Natural Values	*Landscape Value*	It represents the influence of the Wall archaeological remains on land morphology and in shaping the surrounding context
Economic Values	*Touristic Value*	It represents a strong but not primary value in site management, which is anyway integrated with heritage values
	Agricultural Value	It is represented by traditional agriculture and pasturage, which are still a powerful lever for managing landscape and site and it's strongly connected to the aesthetic and historical value of H.W. site
	Non-Use/Non-Market Value (including Bequest Value)	It represents an economic value that is not traded in or captured by markets and is therefore difficult to express in terms of price, for which individuals would be willing to allocate resources/money to acquire and/or protect them

Since the emergence of modern historical inquiry during the eighteenth and nineteenth centuries, the significance of the Wall has predominantly been understood through the lens of Roman-era archaeological and historical artefacts. However, in recent times, there has been a notable shift in perception, with the recognition of a much broader and more diverse range of values and contemporary uses associated with the site. This expanded understanding now encompasses a deeply layered historic landscape that reflects multiple periods and narratives, while also embodying significant contemporary values [37]. The site today takes on a new position, where the integrated landscape of archaeology, and natural and historical heritage is composed as an assemblage of agencies, each of which is recognised through shared values. Indeed, the management policies adopted by the site have influenced the international landscape, creating a historical precedent where the collaboration of private owners, agriculture and pastoralism and culture sustain an entire region.

4 Conclusions

4.1 Values, Cultural Significance and Policies

The presence of heritage in most European cities has led to the search for worthy solutions for issues of great relevance for the preservation of the local built, archaeological, cultural and natural heritage. When contemporary urban transformations meet the so-called *historic urban landscape*, which brings together multiple aspects characteristic of Europe's stratified urban fabric, great changes and exceptional procedures for the local planning system can occur. As pointed out in the previous paragraphs, some authors have shown some limitations of the UNESCO Recommendation on the Historic Urban Landscape, revealing that most of its references to sustainable development were related to the conservation of the built heritage. As David Lowenthal notes, "Heritage is never merely conserved or protected; it is modified—both enhanced and degraded—by each new generation." Conservation, like all social activities, is not objective; it is influenced by the values and perspectives of various individuals and interest groups. Values assign significance to certain objects and places, thereby transforming them into "heritage" [38]. The risk of a heritage-driven approach, when based only on conservation principles attributed through academic or expert knowledge, circumscribes the possibility of a democratic recognition of true values of heritage and so of shared and sustainable policy decisions. This happens unless such an approach is imbued with participatory planning and environmental concerns related to sustainable living in communities [5]. Serving as a unifying theme, landscape enables the consideration of various contributions from multiple disciplines, facilitating a holistic understanding of landscape values. It allows diverse researchers to explore different topics while collectively contributing to a more comprehensive grasp of spatial, temporal, ecological, and cognitive concepts [39]. Moreover, the landscape offers opportunities for collaborative endeavours among disciplines and communities [40]. The growing need to assess and monitor landscapes also calls for the development of open methodologies to evaluate the impact of policy measures and their effects. Furthermore, these methodologies are crucial for sustainable conservation and protection of natural and cultural capital, as well as for territorial planning and landscape management [41].

In this sense, by presenting the case of Hadrian's Wall and its ecosystem, this research attempts to set precedents that serve to identify and recognise the impacts that contemporary interventions have within heritage-rich contexts. Over time, there has been a notable evolution in the understanding and management of the diverse values associated with this heritage site. What used to be considered only for its archaeological presence, today constitutes a multifaceted cultural landscape, made up of practices and strategies, people and actions that have contributed to making this site of great historical and environmental significance.

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A Decision Support System for Cultural and Territorial Infrastructures: A Place-Based and Community-Driven Strategy in Inner Italy

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Abstract. The study presents a methodological approach, characterized by scalability and replicability, aimed at developing a sustainable territorial strategy, supported by a Collaborative Spatial Decision Support System (CSDSS). The main objective is to elaborate a regeneration process for infrastructure and territorial contexts capable of stimulating situated actions within Inner Italy, where urban revitalisation processes grounded in the concept of community archives could be implemented. The CSDSS is tailored towards a place-based and community-driven strategy for the territory of Atena Lucana, in Southern Italy. It unfolds in three interconnected phases: first, a knowledge phase with a comprehensive understanding of the territory through the integration of various data types; second, an evaluative phase including multi-group analysis supported by the SOCRATES method and multi-criteria analysis employing the integration of QGIS and GeoTopsis methods; third, the data output with the formulation of a suitable strategy for territorial sustainability through collaborative decision-making processes.

Keywords: Territorial sustainability · SOCRATES method · GeoTopsis method

1 Introduction

Recent studies and reflections about landscape identify it as a fundamental resource for activating new local development processes, focused on the specificities of the context and capable of including the multiple forms of capital – material and immaterial - that characterise it.

The landscape can be considered the attractive element that gives territories a differential advantage, making it possible to develop change and transition processes, starting with actions aimed at its protection, transformation and regeneration. In this perspective, the processes of hybridisation of its use, non-use and intrinsic values represent an opportunity to face the challenges of regeneration, in which the integration between multiple dimensions, systems of relationships and synergistic and symbiotic bonds among the various tangible and intangible resources can promote new forms of vibrancy and an

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attractiveness, capable of operationalising the ecological, social, economic and cultural transition [1].

To interpret landscapes as multidimensional and dynamic contexts, adopting an active and proactive approach is essential in defining a multiscale place-based and community-led development model [2, 3].

This perspective allows the landscape to take on an interpretative role of territorial characteristics and contributes to the regeneration of collective memory and community ties, initiating and enhancing innovative models and processes aimed at respecting the integrity of existing values [4, 5]. The recognition of existing values is closely linked to the identification of decision-making opportunities and guides the process of strategic thinking towards Sustainable Territorial Development [6].

The research aims to explore territorial sustainability challenges through a circular and incremental methodological approach focused on developing strategies for specific territorial areas.

The contribution tries to understand how to make strategic choices and public policies deeply rooted in the local context and tailored to different landscapes and socio-economic and cultural contexts, through a values-based perspective. This is particularly relevant in Italy's Inner Areas [7], where historically marginalised territories have made it possible to highlight important critical issues in territorial policies, even on a national scale.

Researchers and professionals working in these territories highlight the relevance of environmental, historical-artistic, social, cultural and intangible resources, often unexplored and underutilised [8–10].

To address the challenges posed by Sustainable Development Goals (SDGs) within the territorial systems, this study has identified three distinct research lines. In particular, the four dimensions of sustainability are associated and interconnected with issues related to the territorial concepts of Resilience [11–13], Vulnerability [14–19], and Attractiveness [20–23].

These three lines are intricately interconnected, not only with each other but also with the four dimensions of sustainability. It is important to recognise that any alterations in one of these aspects have a cascading effect on the others. By concentrating on a territorial scale, we can comprehensively examine the processes and interconnections that underlie each of these themes. By delving into the dynamics and relationships among Resilience, Vulnerability, and Attractiveness, and their interactions with sustainability dimensions, we can gain a clearer picture of how these factors collectively influence and shape the territory, outlining multiple and multidimensional regeneration strategies.

To support the public policymakers in developing place-based and community-driven strategies for transitioning landscapes, the research recognises the necessity to structure an incremental, adaptive, and dynamic methodological approach to understand the system of material and immaterial values that constitute the foundation of Italy's Inner Areas landscape.

Based on these premises, the research aims to define a methodological approach for the construction of a Collaborative Decision Support System (CDSS) for cultural and territorial infrastructures in Italy's Inner Area with particular attention to the municipalities of Atena Lucana, Brienza, and Marsico Nuovo (Campania and Basilicata's Regions).

The research focuses on both the physical - disused railway - and not physical infrastructure - a community archive - which become the basis for thoroughly understanding the case study context and developing a sustainable development strategy. The theme of cultural and territorial infrastructure becomes the tool through which landscapes and people could be reconnected, regenerating the system of human and ecological bonds, promoting underutilised and unexpressed resources of places, and networking different actors towards building a collaborative active strategy oriented towards territorial regeneration.

While studies about disused transport infrastructure have been widely addressed in the literature [24–27], only recently community archives have gained great attention due to their importance in collecting collective identities through oral histories, folk tales, exhibitions, images, and other interactions [28]. Defining community archives is a complex operation. An archive is a collection of documents created during practical, legal, or administrative activities, bound by an original link [29]. Therefore, archives become involuntary and consist not only of the documents themselves but also of the relationships between them.

Scotini [30] argues that the archive is not simply a collection of data, documents, or information but a fundamental practice with the power to give visibility and voice to what has not been archived: a repressed and exiled identity, a memory. A community archive is considered an unresolved operation because it arises from the paradox of something that, while aspiring to be archived, escapes archiving.

Flinn [31] states that community archives are basic documentation, recording, and exploration activities of community heritage where participation, control, and project ownership are essential. This activity may or may not occur in association with formal heritage organisations. Caswell et al. [32] assert that community archives can be an alternative to traditional archives, allowing communities to collectively determine what holds lasting significance to them, influence the shared memory of their history, and manage the narratives surrounding their past.

The main objectives of community-based archives could be grouped around five key points: broad participation in all or most aspects of archival collection; from assessment to description to awareness-raising; shared management of cultural heritage between the archival organisation and the broader community it represents; multiplicity of voices and formats, including non-traditional ones present in traditional archives; the archive and collection as a form of activism; and finally, the changing nature of community and identity. These archives serve as an alternative space for the community to make collective decisions about what is valuable and enduring to them and to control how stories about the past are constructed.

To reconnect both landscape and people and present the opportunities given by the adoption of cultural and territorial infrastructures in the research case study, the contribution is structured as follows: in Sect. 2, the case study of Atena Lucana, Brienza, and Marsico Nuovo are presented; in Sect. 3, the material and methods are described; and Sect. 4 presents conclusions.

2 The Case Study

The municipalities of Atena Lucana, Brienza, and Marsico Nuovo in the provinces of Salerno, Campania Region, and Potenza, Basilicata Region, in Italy (Fig. 1) are chosen as the case study. They are part of the territorial macro-area defined as Inner Areas [33].

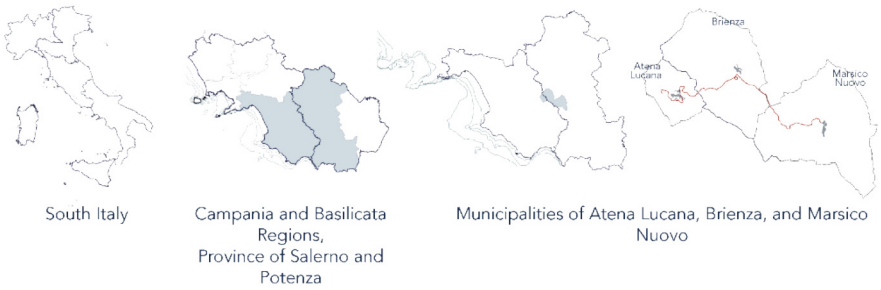

Fig. 1. The Atena Lucana, Brienza and Marsico Nuovo case study

These specific areas are characterised by a process of marginalisation that manifested itself through depopulation phenomena linked to the abandonment of places by the younger segment of the population, which over time moved towards urban centres that offered more services and opportunities in terms of employment and education.

The analysed areas are characterised by a considerable distance from the main urban centres and the essential services (education, health and mobility). At the same time, they are characterised by considerable environmental resources (water resources, agricultural systems, forests, natural landscapes) and cultural assets (archaeological sites, historical settlements, craft centres).

Although Inner Areas can benefit from European and National funding intervention programmes, they suffer an ongoing process of marginalisation, manifested through phenomena of depopulation and abandonment of places, especially by the younger segment of the population, attracted by other centres offering better services and opportunities in terms of employment and education.

The municipality of Brienza is characterised by a medieval village developed all around the Caracciolo Castle. The municipality of Marsico Nuovo is spread on three hills that dominate the Val d'Agri: Civita, the highest with the historic centre that hosts a tangle of alleys and staircases; Portello and Casale, lower, with modern expansion.

Last, the municipality of Atena Lucana is one of the oldest settlements in the Vallo di Diano. Atena Lucana falls within one of the four inner areas of the Campania Region, as it is a sparsely populated area (Eurostat 2011), with high seismic activity and a distance from the Eboli hub between 40' and 75'.

Its dominant position in the valley allows it to have one of the most interesting panoramic centres of the entire Vallo, with a medieval settlement perched on the ancient acropolis. A crucial road junction since Roman times as the intersection point between the ancient Annia and Popilia routes, it still plays a pivotal role today thanks to its proximity to the junction between the A2 Mediterranean and the Val D'Agri fund that connects Campania with Potenza and Taranto.

Recently, the municipality was the winner of the public call Attrazione dei Borghi and thus financed within the resources of the National Plan for Recovery and Resilience (PNRR M13), with a project that envisages the development of a place-based decision-making process to identify and catalogue the most representative dimensions of the territorial heritage.

The three municipalities are connected by an abandoned "Atena Lucana - Marsico Nuovo railway, about 27 km long, inaugurated in 1931 and closed in 1966. It is both the only railway of the "Ferrovie Calabro Lucane connected with Campania and the only one that has been constructed using significant engineering works, such as the Brienza helicoid - which allowed overcoming a considerable elevation to reach the municipality of Marsico Nuovo.

The railway stretch included several stations and stops; among the most important were Atena Lucana Scalo, Atena Lucana, Pozzi, Brienza, Pioppetta, Pergola, Tempa Campitelli, Cappuccini, and Marsico Nuovo. Currently, the railway can only be traced in sections. In particular, the sections between Atena Scalo and Atena Città and between Pozzi and Pergola have disappeared following the modernisation works carried out in the S.S. 598 in the 1970s.

Starting from the reinterpretation of the territorial landscapes and the "Attrazione dei Borghi" project guidelines, the research aims to explore how community archives can serve as cultural infrastructure, interconnected with a territorial system that rethinks the abandoned Atena Lucana-Marsico Nuovo railway.

3 Material and Methods

The research conducted in the inner areas of Atena Lucana, Brienza, and Marsico Nuovo aims to establish a Collaborative Spatial Decision Support System (CSDSS) to enhance the territory's material and immaterial cultural resources. Specifically, the objective is to provide decision-makers with the necessary tools for urban and territorial regeneration processes, facilitating the selection of project interventions or policies that enhance the identity of the selected cultural infrastructures.

In particular, the methodological framework is organised into three main phases (Fig. 2), within which various evaluative approaches and tools are utilised:

- Knowledge Phase;
- Evaluation Phase;
- Data Output Phase.

3.1 Knowledge Phase

In the first phase, the Knowledge phase, four elements relating to the manufactured and natural territory, the railway infrastructure, translations and local culture are explored explicitly to get to know and acquire knowledge of material and non-material elements of the helpful territory for identifying cultural values.

The process of acquiring the territory's material and immaterial elements has been divided into four steps, each with specific objectives and methodologies. Only the comprehensive set of all knowledge provides a clear and complete picture of the territorial

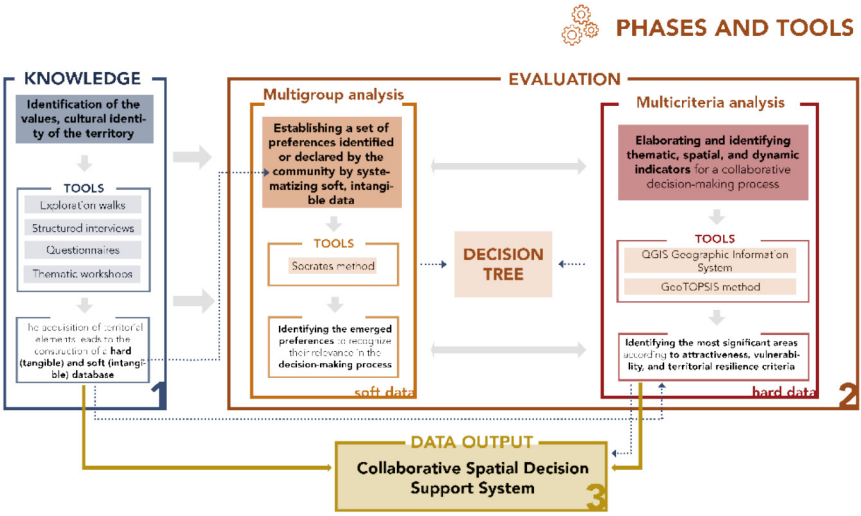

Fig. 2. Methodological approach

reality. The landscape is fully interpreted through direct and everyday experience. However, the different forms of landscape knowledge are characterized by a common framework consistent with how the community perceive and evaluate the landscape itself. This will define the selection of the entire spatial data set that will underlie subsequent evaluation processes.

In particular, the case study is analysed in its entirety through different tools and evaluation approaches:

- Exploratory walks to perceive, get to know and detect strengths and weaknesses of the area;
- Structured interviews, using the CATWOE technique (Customers-Attractors-Worldview-Owner-Environmental), to understand the history and significance of the abandoned railway, to be presented to the community, to understand both the problems that led to its abandonment and the wishes of the community, and identify urban regeneration and cultural solutions that meet the needs of the community.
- A questionnaire to learn about traditions and lifestyles, aimed at residents and non-residents, and characterised by structured questions to identify the values perceived by different local communities. The questionnaire was structured with open-ended and multiple-choice questions and disseminated digitally through the leading social networking channels to engage a wider audience and intercept a multiplicity of complex values;
- Community workshops for the knowledge of cultural resources and values to have moments of confrontation to gather different points of view of the actors involved, which are helpful to understand the local culture, opportunities, and fragilities of the territory.

The analysis of different knowledge approaches begins with the initial steps, logically and substantially, starting from exploratory walks. These walks provide a unique way

to delve into the territory under study, experiencing it, smelling it, listening to it, and making contact with it. The walks have been indispensable for observing the existing conditions and identifying the strengths and weaknesses of the territory. Attention has been mainly focused on the historic centre of Atena Lucana and the former Atena Lucana - Marsico Nuovo railway route. Walking within the historic centre reveals its immense value and relevant importance, overlooking and surrounded by the natural landscape. Three concentric rings make up the entire ancient village, which is an alternation of public space and private space in the houses. Narrow and hardly accessible alleys, cramped. The abandoned railway is a junction point between the three cities but a symbol of missed opportunities and difficulties in this territory. From Atena Lucana to Marsico Nuovo, all the toll booths and stations are clear and identifiable. Four piezometric towers guide the entire route and alternate with typical toll booths' characteristic "outhouses" and external ovens. The untouched nature surrounds what remains of these structures; some are occupied or converted into private residences. Unfortunately, it is not possible to retrace the entire route. Many sections have been cemented over and overshadowed by the road "S.S. 598", buried by modernity.

To understand the abandoned railway issue and explore potential regeneration, involving the community in a structured interview was essential. One-to-one comparisons were conducted using the CATWOE structured interview methodology, which falls within the Soft System Methodology (SSM) and is typically used for solving complex problems. The primary goal of the questionnaire was to define a revitalisation process for the former Atena-Marsico Nuovo railway.

From the responses, a clear desire emerged for the recovery of the old railway line in a wholly naturalistic manner, to create an inter-municipal and interregional connection route capable of attracting schools, sports associations, and social cooperatives. To comprehend the perceived values of the local community and visitors, a questionnaire has been elaborated with open-ended and multiple-choice questions distributed through a multi-platform digital method. This choice was made to engage a broader audience and intercept many complex values. The description and understanding start from the bottom, from the sensations and impressions of individuals, but they have been able to identify indices to support innovative strategies. Understanding which places concentrate values and personal relationships has been the guiding thread throughout the process. The questionnaires were administered to two categories of stakeholders: insiders (those living within the territory) and outsiders (external visitors). The questions were designed to capture the most intangible and shared aspects of the local value scale and were divided into macro groups.

All responses received were processed and represented the proposed question themes. The resulting framework provides a narrative of the territory through the community's subjective values that feed into each other until the definition of a country's identity.

The last tool identified to understand the local culture and grasp development opportunities was active participation in community meetings, which saw the involvement of associations, municipal institutions, the University of Naples Federico II, and the community of Atena Lucana. The meetings took place in Atena Lucana, at the city's

institutional venues, and were moments of active dialogue that provided the opportunity to directly gather different perspectives from the involved actors to understand the territory's vulnerabilities and opportunities.

The process outlined so far has involved robust and active community engagement, which has proven crucial in constructing the database. Indeed, the study acquired through the inclusion of the community in the transformation process has contributed to expanding the community's values and amplifying its potential scope for the future. However, to create a standard filter for processing and interpreting the presented analyses, it is necessary to define - in addition to a shared value system - also a standard symbology that makes the different types of analyses intelligible and can reinterpret them to facilitate comparisons between them. In this sense, an attempt has been made to develop a tripolar reading matrix that, through the concepts of Attractiveness, Vulnerability, and Resilience, provides a scale of preferences among the various design proposals and different levels of analysis; these three concepts were chosen because, for each of them, it is possible to trace strong compatibility with the analysed territorial reality.

3.2 Evaluation Phase

In the second phase, the research focuses on evaluation, which allows for the integration of different approaches and methods. In this phase, a multi-group evaluation is used to identify the preferences expressed by the different actors involved in the process, and a multi-criteria evaluation is used to take into account the different impacts and identify the most satisfactory solutions (Fig. 3).

The aim of this dual analysis lies in the need to have different decision support systems that can offer a multiple and contemporary view of the entire situation analysed; the idea that this methodological choice pursues is to implement a general principle in which it is believed that it is possible to outline a logical reference structure for decision-making problems by organising them according to a model that allows for rational analysis. The chosen approach, therefore, multiscalar and multidimensional, aims to overcome the "limits" of evaluations based solely on preferences expressed by experts or decision-makers. The SOCRATES method – Social multi CRiteria Assessment of European policies – [34] was employed for the multi-group assessment. Through its multi-actor framework, this approach facilitates the management of ex-ante evaluation problems of public policies, enhancing the understanding of the problem's characteristics. The SOCRATES method is significant because it allows for the interpretation of the preferences collected, including the different points of view of the stakeholders involved. At the same time, the multi-criteria analysis is essential for assessing the impact of alternatives, including qualitative and quantitative data. The core of SOCRATES consists of three main components: multi-criteria, equity, and sensitivity analysis. Notably, based on this methodology, a namesake software has been developed, which essentially represents the computer application of a more general theoretical approach defined in the Multi-Criteria Decision Analysis (MCDA), underlying the so-called Social Multi-Criteria Evaluation (SMCE).

The social actors involved in the process were selected taking into account the results of the knowledge phase, and their needs, desires, and preferences were identified and subsequently translated into evaluation criteria. Therefore, in this phase, the data set

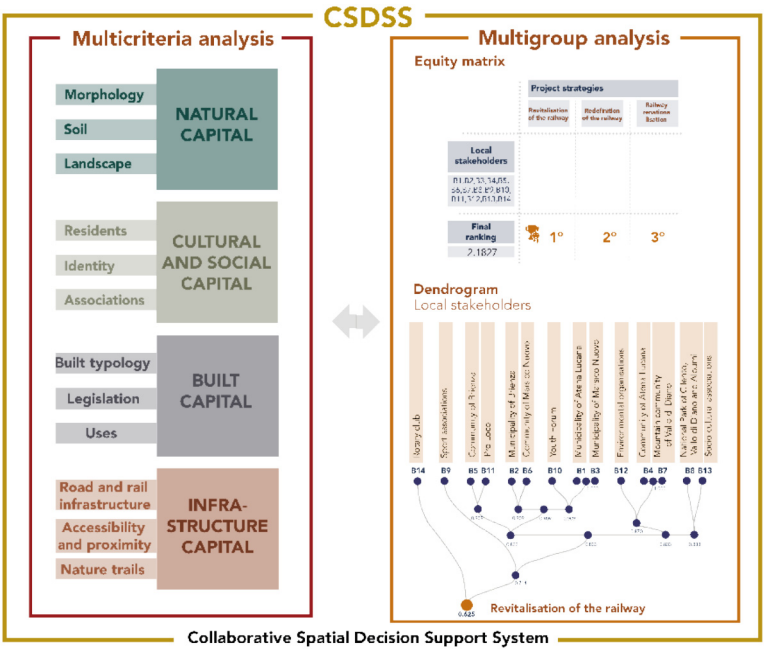

Fig. 3. Multicriterion analysis and multi-group analysis in the Collaborative Spatial Decision Support System

consisting of the results of the cognitive analyses already presented and the mix of quantitative and qualitative information collected was interpreted accurately. Given the complexity of the data collected and, more importantly, the opportunity to structure a standardised and replicable methodology, the open-source SOCRATES platform was used to assess the potential impact of an ex-ante intervention on the former Atena Lucana - Marsico Nuovo railway.

Three alternative projects concerning the abandoned railway were then hypothesised:

1. Comprehensive redevelopment of the entire route;
2. Specific interventions concerning some key elements of the route;
3. No intervention aimed at the renaturalisation of the route.

The multi-criteria analysis of the three alternatives was carried out in terms of four main criteria, corresponding respectively to natural capital, human capital, cultural capital and infrastructure capital. For each of the four dimensions, key objectives have been identified to be achieved through specific actions that can focus on how to improve the abandoned railway. For each of the criteria considered, the impact of the alternative projects was assessed using a qualitative scale, ranging from "very poor" to "very good", with "neutral" as the midpoint.

The results of the multi-criteria assessment of the three alternative projects underline how the comprehensive redevelopment process for the entire railway line would be preferable, able to integrate the specific benefits of a more comprehensive process.

Once the preferred project had been clarified, it was possible to proceed with the "equity analysis", which focused on the evaluation of the alternative projects by the different social actors involved. Each actor was assigned an influence coefficient, calculated based on an influence matrix, which is useful for analysing the relationship between interest and power for each stakeholder.

From this perspective, the possible convergences of interests between the various stakeholders were analysed in order to define acceptable social compromise solutions. Once again, the first project proposal, based on a comprehensive redevelopment of the entire route, appears to be the most attractive design solution, capable of managing potential conflicts and building constructive alliances between the different stakeholders.

The results of the application of the SOCRATES method are the basis for the development of a further assessment, which was useful to verify where it would be preferable to intervene in order to operationalise a territorial sustainability strategy.

This assessment was carried out using the GeoTOPSIS tool in QGIS to spatialise the selected indicators and rank the alternatives according to different criteria consistent with the four forms of capital. Raw data were collected, processed, and examined to develop the reference geodatabase for a comprehensive territorial understanding.

The evaluation process began with the spatialisation of the four criteria identified in the multi-group and multi-criteria analysis, which was used to gain a more conscious and in-depth understanding of the area.

This classification of the mapping of areas and features of the territory was based on the preferences expressed by the community, identifying the perceived values at different scales. Taking into account the four main criteria, the related sub-criteria and the indicators with the specific unit of measurement, the framework of the decision tree was articulated.

The implemented QGIS system allows the combination, manipulation and correlation of different spatial data sets to identify common patterns of elements that inform about the character of the territory; the ultimate goal is to provide a hypothetical decision maker with all the useful and transparent elements for a comprehensive and motivated choice.

Using the GeoTOPSIS tool, the data obtained could be further processed to produce cross-maps combining several indicators.

For this type of territorial analysis, the theoretical reference basis is the construction technique of aggregate measures known by the acronym TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [35]. The GeoTOPSIS method provides a composite index through which it is possible to derive a ranking regarding the phenomenon under examination. In the examined case study, the GeoTOPSIS method allowed us to define a system of preferences based on geo-referenced data regarding the areas most suitable for territorial transformation processes.

The GeoTOPSIS method can address the potential conflicts between the analysis indicators used, such as those in the economic and social domains, by avoiding such conflicts and simply defining a ranking among possible investment zones. The tool used in this case is based on the normalisation of criteria matrices, ensuring that the criteria are comparable and do not disproportionately influence the results. The result is based on the construction of a decision matrix, which represents the evaluations of the alternatives

in terms of the different normalised criteria. A mathematical algorithm calculates the Euclidean distances from the ideal and anti-ideal solutions, minimising the distance from the solution defined as "ideal" and maximising the distance from the solution defined as "anti-ideal", thus providing a comprehensive map of preferences.

4 Results

The structuring of the methodological process through the knowledge and assessment phases, together with the definition of the hierarchical structure of the decision-making process, allows the development of spatial indicators for each of the criteria identified (natural capital, built capital, infrastructure capital and cultural and social capital) to produce a strategic map. By assigning weights and preferences to each of the selected indicators, and by combining quantitative and qualitative items through GeoTopsis, the result maps allow the identification of intervention areas that are more significant for a sustainable transformation of each analysed capital.

In the analysis conducted on the capital dimensions, assumed as criteria, the following elements were mapped: for natural capital, protected areas, agricultural areas, parks and resident population; for cultural and social capital, the number of institutions, third sector associations, sports associations, total population and employment rate; for built capital, the number of existing buildings in the areas, buildings under construction, ruins, protected and safeguarded properties; finally, for infrastructural capital, transportation infrastructure composed by highways, state highways, secondary roads, mule tracks and trails. Spatialisation of these elements produced specific maps, with darker colours indicating preferred areas of transformation (Fig. 4).

Subsequently, through the comparison of the maps of four capitals, it was possible to delineate a unique cartographic reference and a comprehensive Collaborative Spatial Decision Support System (CSDSS) [36, 37], useful in guiding the structuring of future processes, policies and planning activities, in which main interest areas appear to be those along the former railway path, that continues to be an attractive hub both in terms of interconnection and potential development.

The identification of the overall intervention strategy is based on the combination of the impact assessment carried out through the multi-criteria analysis, the potential of the spatial data processed by QGis and GeoTopsis, and the sociological and human aspects studied through the activities developed with the community and local stakeholders through the multi-group analysis, underlining how the ex-ante evaluation is necessary to identify and develop the spatial planning process and local policies.

The final objective of the process is to find a compromise solution among the possible alternatives, which is not only the most acceptable, but which combines the historical and human resources to safeguard the capacity of the area with the needs of the local institutions to look to a different and more attractive future, in which attractiveness is based on a project for the regeneration of the entire railway line between the municipalities of Atena Lucana and Marsico Nuovo.

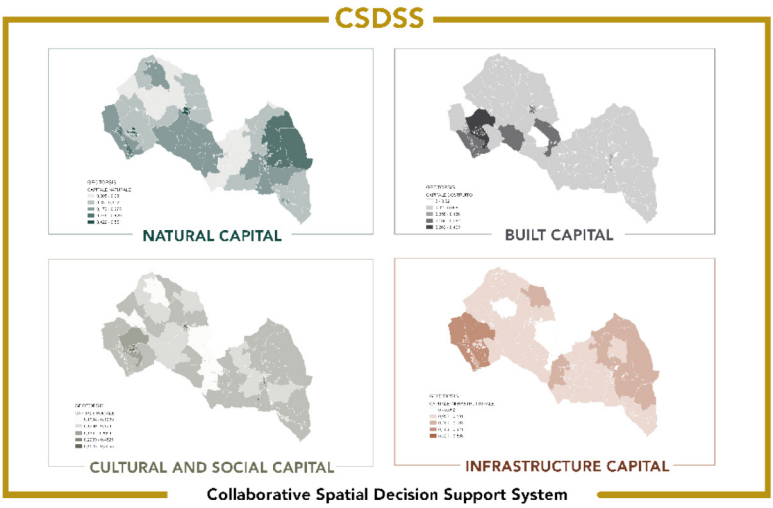

Fig. 4. Maps of the four capital dimensions forming the Collaborative Spatial Decision Support System (CSDSS)

5 Conclusion

The developed contribution has been structured as a starting point, incremental and adaptive, for a collaborative and participatory process on a broader scale, aimed at involving various expertise, different social groups, organisations, and institutions to improve the concreteness of both hard and soft data, as well as the robustness of the evaluation. However, even in this initial experimentation, it is possible to highlight how the community archive and the construction of a georeferenced digital platform emerge as two complementary tools derived from different fields that are handy for addressing sustainability challenges.

The spatialised and dynamic methodological process developed for Atena Lucana, Brienza, and Marsico Nuovo interprets the main characteristics of the territory. It highlights how managing the complexity and heterogeneity of values within a digital platform structured as a decision support system is possible. Different approaches and methodologies have allowed for identifying, describing, and discretising the multidimensional values of the places. The work carried out with the community is an essential part of the process, and the evaluation of intangible assets assumes a key role in analysing the social concept of value in its relationship with spatial data.

The proposed methodology shows that a multidimensional approach, using multi-criteria and multi-group analysis, presents an effective way to discover, acquire, and represent the complex values of the territory. Particular importance is given to the data collection phase and the construction of a flexible and incremental database, where it is possible to exchange information and combine data and indicators to understand the current state and future possibilities of the territorial context.

The study also highlights how GIS methodology, combined with various multi-criteria evaluation methodologies (such as Socrates and GeoTopsis, enabling both qualitative and quantitative data management), can cross complex spatial data. This makes the analysis dynamic and flexible and provides a solid basis for managing the various phases of the decision-making process for marginal territories like Atena Lucana, Brienza, and Marsico Nuovo.

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A Data-Driven Design Approach for Multi-scale Green Infrastructure Design: Integrating Landscape Connectivity and Phytoremediation in the Piedmont Region (IT)

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Abstract. Rapid urbanization, intensive agriculture, and industrial activities in Europe have led to escalating landscape fragmentation and environmental pollution, posing threats to biodiversity, and causing degradation of vital natural resources over time. In response, the imperative for sustainable green infrastructure (GI) development has intensified to effectively mitigate the adverse impacts of human activities on landscapes and enhance their capacity to support life. However, despite the recognized importance of GI in addressing environmental challenges, its design and implementation remains a complex challenge, due to the difficulty to fully grasp and assess how GI provisions link to benefits at multiple scales, and how the latter can be maximized.

This paper introduces a data-driven approach for the integrated and multi-scalar design of GI, leveraging phytoremediation techniques to remediate polluted sites. By employing phytoremediation techniques at the local scale, this approach aims at enhancing local soil and water conditions while simultaneously reinforcing connectivity in regional ecological networks. The proposed approach initiates with a Morphological Spatial Pattern Analysis (MSPA) and Network Connectivity Analysis (MCA) to identify potential ecological sources and assess the impact of designed green corridors on the performance of existing regional networks. Subsequently, mapping and characterization of polluted sites are carried out in a GIS environment to identify strategic areas for the development of GI features at the local scale. This research makes use of the Novara area in the Piedmont region (IT) to test the above mentioned approach. Initial results show that quantifying and integrating landscape connectivity with the transformation of polluted sites is a viable way to optimize GI design allowing strategic design interventions on the regional and local scale. The proposed data-driven design approach offers a holistic solution to the challenges of urbanization and landscape fragmentation by providing a framework that enhances ecological resilience, optimizes resource allocation, and contributes to the creation of multifunctional landscapes.

Keywords: Green Infrastructure · Phytoremediation · Data-Driven Design · GIS

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1 Introduction

The modern era witnesses an unprecedented surge in urbanization, intensified agricultural practices, and industrialization worldwide. This has resulted in the reshaping of natural landscapes and the alteration of their processes, jeopardizing their capacity to sustain life. Rapid transformation has broken up once continuous and healthy ecosystems into fragmented patches, endangering flora and fauna. Furthermore, industrial activities have resulted in contamination of vital resources such as soil, water, and air. The European continent boasts a rich industrial history that has left an indelible mark on its landscapes, caused by the production sector among others [1]. Recent estimates suggest that there are an estimated 2.5 million potentially polluted sites in Europe, with around 340,000 of them confirmed as contaminated and necessitating urgent remediation [2]. Nature-Based Solutions (NbS) are widely acknowledged as valuable approaches for remediating contaminated land. NbS make use of or mimic natural processes to address various environmental challenges, while providing the conditions to enhance biodiversity, mitigate pollution, improve climate resilience, and promote public health and well-being by integrating nature into urban and landscape planning [3, 4].

In particular, contaminated sites remediation can leverage phytoremediation techniques to harness vegetation to extract, sequester, or degrade contaminants in soil and water. Phytoremediation can deliver a range of benefits that go beyond mere pollution mitigation. Moreover, as phytoremediation techniques rely on natural processes to remediate polluted soil and water, they prove more cost-effective than traditional engineering approaches. When integrated into broader spatial design strategies, it becomes a powerful tool for ecological restoration, strengthening degraded ecosystems and enhancing environmental quality and biodiversity. In this regard, wasted land redevelopment through phytoremediation can become a platform for crafting spatial strategies that advance sustainable development addressing multiple spatial scales, akin to the principles of Green Infrastructure (GI) planning and design.

GI are interconnected networks of natural and semi-natural spatial features that provide social, economic, and environmental benefits in urban and rural settings by integrating conservation with land development and infrastructure planning [5, 6] GI planning and design bring together multiple spatial scales, ranging from the small, fragmented system of open spaces in dense urban environments to larger regional scales, tailored to address the unique challenges and characteristics of each context [7]. Embracing this multi-scale approach ensures the safeguarding of pivotal natural areas like forests and wetlands, while also bolstering the ecological integrity of broader networks and simultaneously supporting local needs such as urban, social and economic revitalization of discarded areas.

Nonetheless, limitations in GI design and planning persist, including a tendency to undervalue ecosystem services and overlook territorial perspectives [8], which can hinder effective implementation at regional scales. Challenges also arise from insufficient integration into broader spatial plans [9] and the difficulty of adopting effective multidisciplinary approaches [10]. Additionally, overlooking existing spatial tools can lead to the design and development of green corridors that fail to address all biodiversity requirements [11]. To overcome these hurdles, leveraging available data and digital technologies becomes essential. Such tools empower designers and planners to rigorously

assess the performance of proposed GI interventions and optimize their impacts across multiple scales.

This paper introduces a novel data-driven spatial design approach to integrate and address multiple scales in GI planning. It highlights the use of phytoremediation techniques to remediate contaminated land as part of this approach. By identifying optimal ecological corridors at the regional scale and different typologies of contaminated areas, it pinpoints potential transformative pathways at the local scale, to improve soil and water quality while also bolstering connectivity within broader regional ecological networks.

This contribution is developed in five distinctive sections. Starting with Sect. 2, where the theoretical framework is explained towards data-driven spatial design, green infrastructure, landscape ecology and phytoremediation approach. Subsequently Sect. 3 introduces the methodological approach developed and further its application in the territory of Novara province, Piedmont Region (IT). In here the emphasis is given to the significance of quantifying landscape connectivity in designing for the optimization of GI and to delineate a methodology for the identification of contaminated sites typologies using k-means clustering method. Section 4 presents and discusses the outcomes of the analysis. Ultimately, Sect. 5 synthesizes the findings, highlighting the potential offered by the proposed data-driven design approach. This section addresses, also, the challenges related to urbanization and landscape fragmentation, while underlying the need for ongoing data quality assessment and refinement for practical application.

2 Theoretical Background

2.1 Data-Driven Spatial Design

Data-Driven Spatial Design aims to promote long-term sustainable spatial development by using digital technologies and computational workflows in combination with spatial design principles. It applies principles from urban informatics, science of cities, Geographic Information Science (GIS), and spatial design to spatially-oriented research, design and planning. In this way, Data-Driven Spatial Design can enhance decision-making in spatial design practice, supporting it with evidence-based methods for the planning, design and management of cities and territories, thus moving away from reliance on assumptions [12]. In spatial disciplines, Data-Driven Design provides designers with tools to generate new, systematic, and robust knowledge, offering fresh insights into the functioning of urban and natural systems. By analyzing data collected across various spatial and temporal scales using computer algorithms, this approach identifies social and ecological patterns and trends, unveiling spatial relationships and phenomena [13].

Data-Driven design bridges the gap between research and design, integrating digital tools with more ‘traditional’ methods available to designer. Digital technology amplifies the cognitive abilities of designers by providing computer-based tools and methods, thereby enriching their toolbox for addressing complex spatial challenges like GI planning and design. Throughout such a process, the designer is in charge of selecting the most suitable methods and tools for acquiring data and processing information, synthesizing it into new knowledge and visualizing it across different media, including static and dynamic mappings, plans, 3D models, and beyond.

When integrated into GI planning and design, data-driven approaches bring about evidence on environmental conditions, including climate patterns, hydrological dynamics, biodiversity and land use, among others. This enables designers to swiftly pinpoint areas requiring green infrastructure intervention. Such approaches facilitate the optimization of time, economic efforts, and resources by identifying the most effective solutions for specific environmental challenges and prioritizing projects to deliver multiple benefits to both environment and society. Additionally, they establish frameworks for monitoring the performance of GI over time and evaluating their efficacy. Moreover, as GI can support climate change impacts adaptation, they can support smarter, faster, and more holistic adaptive solutions [14] by offering standardized workflows that harness the wide range of openly available environmental data from European platforms like Copernicus, the European Union's Earth Observation Program, integrating it with national, regional and local datasets. Finally, Data-Driven Design Approaches aspire toward reproducible, scalable, and automated workflows, fostering clearer and more transparent decision-making processes and promoting replicability in local contexts.

2.2 Landscape Ecology and the Role of Green Infrastructure

To properly address the redesign of existing green infrastructure, this proposed methodology draws from landscape ecology theory and principles [15]. Landscape ecology focuses on the study of ecological patterns and processes within structured mosaics of adjacent, heterogeneous ecosystems [16]. It categorizes landscape features into three primary components: patches, corridors, and matrix. Patches are defined as separate areas of natural vegetation, corridors denote continuous connections between patches, and the matrix encompasses the remaining existing mixture of landscape components [15].

Landscape Ecology principles have been extensively integrated into the assessment of ecological networks and connectivity, contributing to the understanding of ecosystems' qualities like their composition and configuration [17], and their capacity to deliver ecosystem services across urban and natural landscapes [18]. It emphasizes the role and the significance of ecological networks in achieving landscape sustainability, as more connected networks better sustain life and biodiversity [19–24]. Ecological network connectivity is an essential aspect to be taken into account for wildlife conservation, serving as a foundational element for conservation planning and landscape management. The value of connectivity is highlighted in the context of landscape structure, where it is quantified as either structural connectivity (the pattern of the network in a given space) or functional connectivity (how a network is actually used) [18]. Therefore, designing green corridors to enhance connectivity is one of the main objectives in GI planning. Designing green corridors to bolster connectivity in spatial design traditionally involves visually exploring landscape patterns across various thematic layers on a map. These layers depict physical and functional aspects of a landscape, such as morphology, water system, protected ecological or high biodiversity areas, mobility infrastructures, land use, among others. By identifying and qualitatively evaluating the impact of spatial opportunities to strengthen corridors and connect existing ecological patches, designers can propose transformative actions for underused or abandoned areas. They can also pinpoint natural or man-made features hindering animal movement along ecological

corridors, like mobility infrastructure. While visually investigating landscape patterns is a valuable method, it lacks the ability to quantify the impacts of proposed design alternatives. GIS-based methods and tools enable the measurement of landscape connectivity and support the assessment of proposed spatial configurations by integrating a quantitative component into the design process. This quantitative analysis guides designers in decision-making by assessing the current conditions of a landscape and possible spatial configuration to optimize the connectivity of ecological networks and identify strategic areas for redevelopment.

2.3 Phytoremediation and Adaptive Transformation

Environmental pollution caused by human activities is impacting the quality of our living environment. In recent years, both in the urban and agriculture environment there has been an increasing recognition of the critical importance of soil fulfilling its natural functions [25]. The concerns about healthy soil have been caused by diverse factors such as accelerated climate change, geopolitical tensions, and the constraints imposed by planetary boundaries, such as resource scarcity, biodiversity loss, desertification, and pollution [26]. Phytoremediation related to soil is considered a valuable contribution for a clean healthy soil. It is often studied from the specific perspective of soil remediation and mentioned as a nature-based alternative to traditional chemical and mechanical solutions [27]. As an example, in 1997 a new masterplan for Westergasfabriek in the Amsterdam west area was designed following these principles. Central to the approach was the necessity to treat the contaminated soil on site instead of transporting it offsite. A cut-and-fill balance was planned, expecting new added cleaned soil after displacing polluted soil. The polluted soil was then reused to reshape the area creating a new system of small hills where the phytoremediation process was taking place. Instead, all around the buildings the existing ground levels were maintained. Nowadays the area serves as a multifunctional public space where some of the former industrial buildings host event and entertainment places. The large park is a relief for the densely inhabited neighborhoods in the surrounding areas [28]. In general phytoremediation offers several advantages over other remediation strategies: low cost and limited maintenance, zero impact on the environment due to the nature of the process, and large public acceptance as an attractive green technology [29].

Being exposed to a variety of natural allelochemicals and xenobiotics, plants have developed diverse detoxification mechanisms of organic compounds [30] to thrive in conditions altered by intense anthropic activity [31] and alleviate pollution. In addition, phytoremediation offers potential beneficial side-effects, such as erosion control, site restoration, carbon sequestration, and feedstock for biofuel production [31, 32]. It can contribute to increasing the biodiversity in the area subject to remediation, such as the case of the Landschaftspark in Duisburg-Nord, Germany. When the former steel works closed in 1985, the site was left highly polluted specially by heavy metals. Although the project did not address phytoremediation as the main project's strategy, it is an interesting example of how phytoremediation can be injected in the design process as a strategy to effectively provide new healthy local ecologies and subsequently more attractive public amenities. A variety of treatments to extract and secure contamination were part of the design and nowadays the park has become a refuge for rare and endangered plants,

while a new ecology is returning to the site [34]. By means of phytoremediation, a chain of subsequent activities may arise and set the conditions for a livable and sustainable city. Moreover, as the remediation process reduces the concentrations of contaminants, an increase of soil prices is often likely to be expected [27]. The Park de Ceuvel in Amsterdam [35] is a small-scale intervention on a brownfield, where the soil remains untouched while cleaned up with Phyto-solutions, and the implementation of active programs revitalized the area. The area has been giving place to valuable workspace, hospitality, meeting places and a green outdoor space. After the opening of De Ceuvel, the surrounding neighborhood became more attractive and consequently housing prices arose.

During their process Phyto-plants have the capacity to uptake contaminants from the soil at a slow rate. Therefore, achieving a significant reduction in contaminant of soil through phytoremediation often necessitates more than a decade. This implies that the design must take into account long-term processes that take place in polluted sites and propose extra programs including temporary uses of the space to allow incremental added values in the area. In this perspective, plants play a crucial role in enhancing the quality of life for people and contrasting climate change, as larger plants and trees provide shade, which helps mitigate temperature increases during summertime, thereby fostering a more hospitable environment. All these physical interactions of plants with the environment improve the quality and livability for people, leading to a better social climate environment [27].

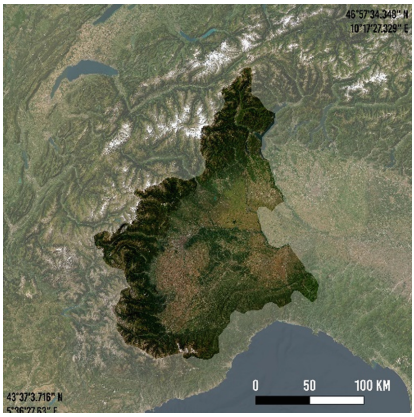

Fig. 1. Study area of Piemonte, IT

3 Materials and Methods

3.1 Study Area

The study area is located in the region between Turin and Milan (Italy), and spans approximately 14,000 km2 within the Piedmont administrative Region (Fig. 1). Bordered by the Alps to the northwestern side, the Turin hills to the south, and the Ticino River to the

east, it holds a crucial position in Italy's economic and industrial landscape. Indeed, this region lies within the historically renowned Italian Industrial Triangle, which contributed significantly to the growth of the country, accounting for 37.7% of the national industrial sector's value added [36]. The Po Valley, where the area is located, is also renowned for its fertile plains and temperate climate, serving as a vital agricultural hub within Italy and the EU. However, rapid urbanization has led to land-use conflicts resulting in habitat fragmentation and biodiversity loss [37, 38]. Moreover, contamination issues from intensive land use further exacerbate the challenges faced by the region. Given these complexities, the study area presents a compelling case for investigating strategies to enhance regional connectivity of the natural and semi-natural landscape through the redesign of GI in contaminated environments.

3.2 Data Sources

As this study aims to introduce a methodology that is highly replicable across diverse spatial contexts with similar landscape conditions in the EU, key to this approach is the use of accessible and open-source data and software. The primary software tools utilized include GeoDa 1.22[1], QGIS 3.23[2], GuidosToolbox 3.3[3], and Conefor 2.6[4].

Spatial data used for this study is sourced from authoritative repositories such as Copernicus Land Monitoring Service and open-access datasets sourced from the European Environment Agency (EEA), the Piedmont Region web-GIS platform, Open Street Map, and Google Maps/Street View. Table 1 provides an overview of the thematic layers used in the research, and their respective sources.

Table 1. Data sources overview

Theme	Thematic Layer	Source
Land-Use / Land Cover	CORINE Land Cover 2018 Vector	Copernicus Land Monitoring Service
Contaminated sites	Anagrafe di siti contaminati (ASCO)	Regione Piemonte - Servizi ambientali
	European Pollutant Release and Transfer Register (E-PRTR)	EEA
Site imagery	Google Street View Static API	Google
Street & railroad infrastructure	OpenStreetMap Overpass Turbo API	OpenStreetMap

(*continued*)

[1] https://geodacenter.github.io
[2] https://www.qgis.org
[3] https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/
[4] http://www.conefor.org

Table 1. (*continued*)

Theme	Thematic Layer	Source
Vegetation	Banca Dati Territoriale di Riferimento degli Enti (BDTRE) - Vegetazione	Regione Piemonte
Buildings & structure	Banca Dati Territoriale di Riferimento degli Enti (BDTRE) – Edifici e antropizzazione	Regione Piemonte

3.3 Regional Scale: Landscape Connectivity Analysis

The landscape connectivity of the study area at the regional scale was evaluated using two distinct approaches: Morphological Spatial Pattern Analysis (MSPA) and Graph-Theoretic Connectivity. The following paragraphs provide a concise introduction to each method.

Morphological Spatial Pattern Analysis (MSPA). Morphological Spatial Pattern Analysis (MSPA) serves as a valuable tool for classifying and segmenting binary patterns into seven distinctive categories. This raster-based method employs a single parameter to classify each pixel based on its spatial surroundings utilizing mathematical morphology operators [39]. These categories encompass cores, edges, perforations, bridges, loops, branches, and islets. The application of MSPA in spatial planning and landscape architecture aligns with Godron & Forman's landscape ecology theories [15], facilitating a comprehensive assessment of landscape structure. The adoption of MSPA has gained considerable attention in landscape conservation and planning studies, contributing to the establishment of landscape connectivity principles and the development of ecological network plans [40]. Furthermore, MSPA's scalability has led to its integration into GI planning at the urban scale, underscoring the significance of ecological connectivity in urban settings [41]. MSPA coupled with Geographic Information Systems (GIS) in planning ecological landscapes is substantial in GI planning and design. GIS provides a powerful platform for spatial analysis, enabling the integration of landscape metrics and the visualization of landscape patterns, such as the identification of spatial distribution of ecological features.

In this study, MSPA is used to identify ecological sources constituting the primary ecological structure of the region. The eight-neighborhood analysis method in Guidos Toolbox 3.3 software was employed for landscape pattern analysis. Given MSPA's suitability for analysis across various spatial scales, selecting fitting parameters was crucial for obtaining accurate results. Based on literature, the raster input resolution was set to 10mx10m, with an edge width of 5, resulting in 50m edge width. Core areas exceeding the threshold value of 8ha were chosen as ecological sources for connectivity analysis at the regional scale.

Graph-Theoretic Connectivity Analysis. Graph theory offers a robust framework for representing and analyzing landscape connectivity, offering insights into spatial relationships emerging from landscape structure and patterns [42]. While MSPA focuses

on the identification of patches, corridors, and other structural landscape components, the graph-theoretical network approach aims to highlight connections between these elements. Representing different components as nodes connected by links enables the visualization of a network on a map. Translating structural landscape components into a node-based network allows for more in-depth accurate calculations of connectivity between individual structural elements [42–44].

Conefor 2.6 software was used for Graph-Theoretic Connectivity Analysis (GTCA). Ecological sources previously identified in MSPA were imported as nodes, each carrying a unique identifier (ID) and their extent area. Conefor 2.6 software facilitates two types of landscape connectivity analyses, providing several indexes. This study primarily utilizes the Probability of Connectivity (PC) Index, defined as the probability that two randomly placed animals within the landscape fall into interconnected habitat areas, to calculate landscape connectivity. PC is non-binary and indicates lower connectivity whenever the distance between patches increases [45]. Connectivity between two sources is represented as the probability that species would travel from one source to another based on mean dispersion values.

To calculate connectivity with Conefor 2.6, several input parameters where used. The mean dispersion distance of the Western Honeybee (Apis mellifera L.) was used as representative value for pollinating species within the region, based on Hagler et al. [46]. Moreover, the Link Improvement-function in Conefor 2.6 allowed the assessment of potential connections between ecological sources. The impact of potential connections was quantified through dPC connector values, with higher values representing potential green corridors with a greater impact on overall landscape connectivity, prioritized in GI planning and design.

3.4 Local Scale: Mapping and Characterization of Polluted Sites

Mapping Contaminated Sites and Typology Analysis. In order to incorporate contaminated sites as key elements in the redesign of green infrastructure (GI), it was essential to comprehend the spatial distribution and conditions of these sites. To achieve this, various sources such as the European Pollutant Release and Transfer Register (E-PRTR) and the Anagrafe Regionale dei Siti Contaminati (ASCO) of Piedmont Region were collated and standardized within the QGIS environment. This process aimed to create a comprehensive and cohesive map of contaminated sites in the region. However, the available information on pollution sources, intensity, types of pollutants, and site conditions was often incomplete.

Nonetheless, a geodatabase was developed, containing information about the geometrical and spatial information for each polluted site, as well as information on size, former use, type of pollutant and polluted media. This information was complemented with information on the surrounding predominant landscape. For missing data on current use of the sites, a neural network was established to approximate the missing data on operability. Using QGIS and Dutch Cadastral data, which does contain detailed information on operability of building, the coordinates of 7186 inoperable and 7501 inoperable buildings were extracted. Google's Street View Static API and Python, images from Google Street View were downloaded of these buildings. As not all of these buildings

had adequate imagery, this resulted in 4,340 images of operable buildings and 2,345 images of inoperable buildings. A neural network based on TensorFlow was developed, focused on image classification and trained on the extracted Google Street View imagery. Using the same approach, imagery for the contaminated sites within the research area were extracted. Using the neural network, these sites were classified as either operable or inoperable. This data was added to the existing geodatabase.

To characterize contaminated sites, a K-means cluster analysis was conducted to identify clusters in GeoDa. These clusters corresponded to typologies of the contaminated sites. Following the elbow-method, an optimal k-value of 5 clusters was determined.

Phytotechnologies and Design Solutions Suitability Assessment. Literature review and design references were used to design spatial interventions on the local scale. These interventions are linked to the aforementioned contamination site typologies based on spatial configuration and suitability within the spatial context. Suitability for contamination type and concentration, applicability in combination with soil characteristics and climate aspects are not taken into account yet. Detailed implementation of the spatial design interventions, including the plant species for phytoremediation, phasing based on contaminant types, maintenance regime, etc. are carried out for the specific characteristics of the individual site that is remediated.

4 Results and Discussion

4.1 Landscape Connectivity Analysis

The MSPA results revealed the ecological landscape composition of the Piedmont region, identifying 1699 ecological core areas, which account for 16,60% of the entire landscape (Fig. 2). The majority of these core areas are notably large, with sizes exceeding 40 ha constituting 15,81% of the overall landscape. These substantial ecological sources are mainly located along the foothills of the Alps, the Turin hills in the south, and the riparian green structures along the Po River and its main tributaries.

There are 37 cores with a size between 8ha and 40ha in the research area, comprising 0,48% of the total landscape. The ecological cores are mainly located in the plains nestled between mountainous regions; most of the former are located near the larger ecological cores of Piedmont region. Concentration of ecological cores decreases when the distance to the large ecological cores increases.

A total of 203 ecological cores with an area larger than 8 ha were selected for the connectivity analysis in Conefor. Table 2 provides an overview of the categorized ecological features.

The assessment of the ecological connectivity results in overall landscape connectivity values of 287.25x10^9 for PC and 53.5961.5 for the Equivalent Connected Area (ECA(PC)). The map in Figure X offers a graphical depiction of the link enhancement analysis performed in Conefor 2.6. It illustrates the effects of reinforcing existing connections and introducing new ones between habitat patches, with a color gradient ranging from blue (representing minimal impact) to red (signifying high impact). Due to computational limitations and processing considerations, a threshold of maximum length

20km was imposed. Additionally, a lower threshold of 5 km was applied, as corridors shorter that this were considered unsuitable for regional-scale development projects. Results show that several areas with a notable concentration of potential links are evident across the study area. Predominantly, these hotspots are situated along the foothills of the Alps, the Turin Hills, and the region between the Po River and its primary tributaries. Notably, the southeastern sector, encompassing the area between Mortara and Pavia, exhibits a high density of promising links. However, it was excluded because it lacks sites requiring remediation. On the other hand, the area extending from Chivasso to the foothills of the Alps showcases both high-potential links and a significant presence of wasteland. Yet, the monotonous and densely industrialized landscape was deemed unattractive from a design standpoint. An advantageous balance between contaminated sites and high-impact links is observed in the area encompassing Vercelli, Novara, and the Ticino Valley Natural Park. Here there is a high density of contaminated sites dispersed throughout a varied landscape including agricultural areas, riparian zones, urban centers, and industrial zones. The selected corridor linking Vercelli and the Ticino Valley Natural Park boasts a dPC value of 0.34, positioning it in the top 4% of potential link enhancement. Additional connections between Vercelli and Novara and the Ticino River contribute further to the enhancement of landscape values.



Fig. 2. MSPA results

Table 2. Statistics on landscape composition from MSPA

Component	Ratio (Core/Area)	Count
CORE(s) [green]	1.38/0.31	1466
CORE(m) [green]	2.11/0.48	135
CORE(l) [green]	69.52/15.81	68
ISLET [brown]	0.09/0.02	31

(*continued*)

Table 2. (*continued*)

Component	Ratio (Core/Area)	Count
PERFORATION [blue]	2.79/0.63	198
EDGE [black]	19.19/4.36	1046
LOOP [yellow]	0.11/0.03	158
BRIDGE [red]	0.99/0.23	1246
BRANCH [orange]	3.80/0.87	21633
Background [grey]	--/77.26	505/37158230

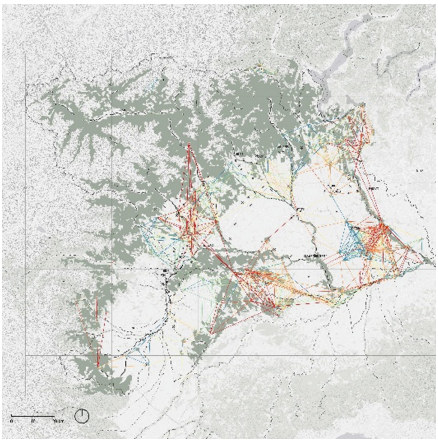

Fig. 3. Results from Link Improvement analysis in Conefor 2.6. Showing dPCconnector values.

4.2 Contaminated Site Typologies

To understand the spatial distribution of polluted areas, 171 of the contaminated sites within the previously selected corridor area were mapped and researched. Available data included plot size, presence of buildings and/or structures, surrounding context and land use, and site operability. Regrettably, operational status data for contaminated sites were not always readily accessible. To address this gap, a Convolutional Neural Network (CNN) was employed for image recognition. Using the images sourced from Google Street View, the operability status of the sites was determined, and results were subsequently added to the geodatabase to perform the cluster analysis in GeoDa to identify five typologies of contaminated sites.

K-means cluster analysis in GeoDa resulted in five clusters (Table 3). Using these typologies, design strategies and interventions can be established to redevelop these sites into more sustainable locations and make them integral parts of the GI planning and design process using phytoremediation and other nature-based solutions.

Typologies. Interpreting the results from the cluster analysis leads to 5 different typologies of contaminated sites. These are the typologies:

Table 3. Results from k-means clustering of the 83 remediation sites.

Cluster 1	*Mean*	*Median*	*Mode*
Structure [y/n]	*0*	*0*	*0*
Plot size [sqm]	*2404*	*1093*	*-*
*Land cover**	*2.2*	*2*	*2*
Operability [y/n]	*0.53*	*1*	*1*

Cluster 2	*Mean*	*Median*	*Mode*
Structure [y/n]	*1*	*1*	*1*
Plot size [sqm]	*4650*	*3529*	*-*
*Land cover**	*2.28*	*2*	*2*
Operability [y/n]	*0.64*	*1*	*1*

Cluster 3	*Mean*	*Median*	*Mode*
Structure [y/n]	*0*	*0*	*0*
Plot size [sqm]	*2404*	*1093*	*-*
*Land cover**	*2.2*	*2*	*2*
Operability [y/n]	*0.53*	*1*	*1*

Cluster 4	*Mean*	*Median*	*Mode*
Structure [y/n]	*1*	*1*	*1*
Plot size [sqm]	*4650*	*3529*	*-*
*Land cover**	*2.28*	*2*	*2*
Operability [y/n]	*0.64*	*1*	*1*

Cluster 5	*Mean*	*Median*	*Mode*
Structure [y/n]	*0*	*0*	*0*
Plot size [sqm]	*2404*	*1093*	*-*
*Land cover**	*2.2*	*2*	*2*
Operability [y/n]	*0.53*	*1*	*1*

**For land cover applies: 0 = nature, 1 = agricultural, 2 = urban, 3 = industrial.*

- Cluster 1 - Urban Incidents: These sites are characterized by localized contamination resulting from incidents like spillage or pipeline bursts. Often small and devoid of buildings or other structures, and located in the immediate surroundings of urban areas, they may be fenced off. These sites are ideal for transformation into social programs or parks, combining urban functions with phytoremediation practices (Fig. 4).
- Cluster 2 - Small industries/Commercial areas: these sites are typically found in urban areas or toward the edges of industrial zones. Contamination arises from industrial activities such as spillage or mismanagement of waste or other products. The mean plot size of these features is relatively small (approximately 0.4 ha), and are often still active (Fig. 3). Redevelopment strategies may involve buffering the sites with vegetation, landscaping, and integrating green energy production with phytoremediation practices.

- Cluster 3 - Polluting agriculture: these are medium to large scale sites outside urban cores, contaminated with pesticides, organic pollutants, or heavy metals due to agricultural practices. Sites can sometimes present structures or buildings. Design strategies for this typology could encompass the reintroduction of sustainable agriculture by introducing tolerant crops together or in rotation with phytoremediation plant species, creating agritourism by redeveloping the existing structures or rewilding.
- Cluster 4 - Industrial giants: mega-sized heavy industry sites in industrial zones, often still active and polluted due to processing of harmful material. Redevelopment strategies for this typology may involve buffering from other (urban or agricultural) land uses, reafforestation, or development of green energy solutions.
- Cluster 5 - Peri-Urban Plains: these are large contaminated plots due to former activity, often found at the edge of the urban cores, like the Silvio Piola Sports Park in Novara or the former airport of Vercelli. Areas within this typology typically do not have any structures, and are completely abandoned and gated to prevent human interaction with the contaminants. As these locations often form the border between urban areas and the agricultural landscape, these areas can be redeveloped into peri-urban parks or used for rural-urban integration with orchards or community gardens.



Fig. 4. Example sites of Cluster 1 – Urban Incident (Left) and Cluster 2 – Small Industries (right)

5 Conclusions

The implementation of a data/driven design approach in GI planning and design within urban, peri-urban and rural landscapes, as demonstrated in this research, offers significant potential to improve the efficiency and the effectiveness of the design process, bridging together different spatial scales and informing strategic decision-making in the design process. By synthesizing existing literature into a comprehensive approach and using different digital tools, this study showcased the role of data as a primary design input at both regional and local scales. The identification of potential green corridors in the Piedmont Region, together with the classification of contaminated sites into distinct typologies, provides valuable insights for devising site-specific design interventions and strategies that can generate benefits on larger scale networks in terms of ecological connectivity and biodiversity.

The integration of phytoremediation and nature-based solutions emerges as crucial elements in transforming contaminated sites into integral components of the regional green infrastructure network in the study area, where multiple potential sites for GI-design were identified. MSPA showed 203 ecological cores with a relevant area size of over 8 ha. While the largest ecological sources are situated in the mountainous and hilly areas of the Alps and the Turin hills, and in the form of riparian zones along the main rivers, a great number of ecological sources were found in the plain. Overlaying the identified ecological sources with the mapped contaminated sites allowed the informed selection of the design area. After conducting a connectivity analysis, the area between the cities of Vercelli, Novara and the Ticino Valley Natural Park was selected as the location with a high potential impact on ecological connectivity. This area was chosen because of the high concentration of contaminated sites and a dynamic landscape consisting of urban cores, agricultural landscapes and industrial zones.

On the local scale, a data-driven analysis was used to identify different typologies of contaminated sites and classify the sites accordingly. A k-means cluster analysis based on relevant criteria was conducted in GeoDa. The resulting clusters were based on plot size, presence of buildings/structures on the site, operability of the sites, and the (surrounding) land cover. This data was gathered from the Corine Land Cover-dataset, cadastral data, OpenStreetMap and Google Street View-imagery, ensuring widespread accessibility and availability for different application locations.

The outcomes of the k-means analysis revealed five distinct typologies of contaminated sites: A. Urban Incidents, B. Small industries, C. Polluting farms, D. Industrial giants, E. Peri-urban plains. For each of the abovementioned typologies, several design interventions and strategies were identified and served as foundational constructs for devising site-specific design principles that help integrate contaminated sites into a broader green corridor redesign strategy.

However, the efficacy of this approach is contingent upon the accuracy and the availability of input data. Challenges such as incomplete or missing data, lack of homogeneity of datasets from different agencies or administrative entities, and biases in training and input data underscore the importance of thorough data auditing for the practical application of this approach. For instance, out of the 171 sampled contaminated locations, only 83 had accessible imagery, resulting in a significant decrease in the sample size for the CNN. Additionally, assessing contamination extent relies on cadastral data for plot size, yet it's crucial to recognize that contamination can extend beyond administrative boundaries, potentially affecting areas outside the delineated plots. Despite these challenges, the data-driven design approach holds promise for guiding strategic decision-making processes in GI planning and design.

Given its data-driven nature, the efficacy and precision of this approach, along with the subsequent formulation of design strategies and decisions, are highly dependent on the accuracy of the gathered input data. Throughout the course of this case study, the presence of deficient or erroneous data has caused inconsistencies within the analytical outcomes. E.g. among the 171 sampled contaminated locations, merely 83 possessed available imagery, meaning a substantial reduction in the sample pool. Furthermore, in assessing the extent of contamination, reliance on plot size derived from cadastral data is necessitated. Nonetheless, it is imperative to acknowledge that contamination is not

bound by administrative boundaries, thereby potentially manifesting in areas beyond the delineated plot area. Additionally, certain contaminated sites are situated within public spaces, devoid of definitive cadastral boundaries, resulting in null values for plot size. Compounding these challenges, both training and input data utilized for analysis with the CNN frequently exhibit biases, censorship, misalignment, or alterations, thereby exacerbating the complexity of operability assessment via image recognition. Many instances of erroneous representations within images, including misidentification of structures, delineation of merely the surrounding public space bordering the actual site, or presence of blurred regions due to stitching or censorship in Google Street View, further decrease the accuracy of the analysis. A comprehensive data audit is an important prerequisite for this approach to become applicable in practice.

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Introducing Principles of Antifragility in World Heritage Management Evaluation Tools: The Case of City of Vicenza and Palladian Villas of the Veneto

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Abstract. This paper explores the integration of principles of antifragile planning in the systems of governance and assessment tools for supporting the management of World Heritage Sites.

The paper argues, after describing the management and evaluation procedures used by UNESCO for monitoring the effectiveness of World Heritage, such as Enhancing our Heritage toolkit, that these procedures focus primarily on maintaining the Outstanding Universal Value of World Heritage properties, without considering the possible implications in respect of the wider social, economic, and environmental context.

In this respect, the aim of the paper is to orient a more complete assessment tool that considers the relationship and the reciprocal impacts between property and wider setting. Hence, the paper presents the principles of antifragile planning as a framework of orientations that can contribute to World Heritage evaluation tools. Hence, the paper proposes an assessment tool which integrates existing assessment tools developed by UNESCO for evaluating the management of World Heritage Sites and principles of antifragility to orient the policy design. Finally, we discuss the case of the World Heritage Site City of Vicenza and Palladian Villas of the Veneto, which lets us use the proposed assessment tool during the process of updating of its management plan, in force at the time of writing.

The tool shows, as results, that the different approaches integrated are complementary and that this integration is a possible way to achieve a wider assessment tool that can address the management policy design in terms of antifragility. This paper aims to contribute to the development of assessment tools which include the antifragile dimension to enhance a policy design for the management of World Heritage properties effective for the property and its surroundings.

Keywords: World Heritage evaluation tools · Antifragility · Management

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1 Introduction

"Heritage places depend on their setting and vice versa".

UNESCO, Managing Cultural World Heritage (2013).

The Convention adopted by UNESCO in 1972 [1] is structured around the identification and protection of the Outstanding Universal Value of cultural and natural properties that, once the designation is obtained, become part of the World Heritage List. The conservation approach looks after the preservation and protection of the Outstanding Universal Value —OUV— of the properties in the long term.

According to the UNESCO Operational Guidelines, the World Heritage Sites must have an appropriate management plan. The main objectives of the management plan are to ensure the effective protection of the properties, to maintain their Outstanding Universal Value and to promote their protection and enhancement. Management Plans require mandatory implementation and periodic evaluation in order to be updated [1]. Ensuring the effective protection of the property is entrusted to the Management Plan whose effectiveness is then delegated to the implementation of the Monitoring Plan [2]. The central goal of conservation is then secure—or not secured—by site management that may involve different private actors and different institutional levels.

Among the tools proposed by UNESCO to support and orient local actors in developing management and monitoring plans there is the *Enhancing our Heritage Toolkit 2.0* —EoH toolkit— [3]. The EoH is a set of tools for assessing the effectiveness of the management of World Heritage sites [4]. One of the topics of the toolkit is the management *cycle* which represents the repetition of processes that are, over time and with *experiri* [5] adapted, adjusted, modified, implemented to achieve the desired outcomes [3].

Despite the impact of management practices is not strictly on the individual property but also on its wider context [2], the twelve tools in the toolkit do not include specifically aspects related to the relationship between the nominated heritage the context. In fact, the main goal of protection of the heritage focuses primarly on maintaining the Outstanding Universal Value of the properties, without considering the possible implications on the wider social, economic and environmental context [6]. This has often resulted in conflicts between conservation objectives and development needs at World Heritage Sites [7]. UNESCO's tools may appear as, in the words of Hirschman, *all-encompassing programs* that are in danger of being ineffective due to the equal importance given to the multiple aspects to be considered [8] in the evaluation.

Hence, we introduce the principle of antifragile planning [9, 10] –in terms of policy design planning— as a framework of orientations which can guides the management plan considering the interdipendence between the property and its wider setting and their reciprocal impacts. Principles of antifragility used in the monitoring and assessment tools may be important to the achievement of a management plan that is best suited to ensure that the presence of the World Heritage Site is beneficial for local development, beyond the boundaries of the *core zone*.

The principles of antifragile planning [9] are introduced as possible tools to integrate with the existing ones proposed by UNESCO in the assessment of the World Heritage and its management systems and interests [11]. The approach is multiscalar [12].

The sections below will examine: in Sect. 2, UNESCO management and evaluation tools, with a particular emphasis on Enhancing our Heritage toolkit; in Sect. 3, the focus will shift to the concept of antifragility in policy design planning and its principles; in Sect. 4, will be presented the hypothesis of integrating the antifragile principles with the EoH toolkit in the case study of Site part of the World Heritage List *City of Vicenza and the Palladian Villas of the Veneto*; and finally this paper draws conclusions on aspects that can contribute to the development of governance tools for the antifragile management of World Heritage properties.

2 Management and Evaluation Practices of UNESCO

The World Heritage system is based on the Convention Concerning the Protection of the World Cultural and Natural Heritage, adopted by UNESCO in 1972 [2]. The Convention, as a value-driven approach to heritage preservation and management, is structured around the identification and protection of the Outstanding Universal Value of properties that, once the outstanding universal value of a site is recognised, become part of the World Heritage. In the WH framework, the preservation of the OUV in a long-term perspective is the goal of management. And the management of the goods is the process that safeguards the heritage.

2.1 Management Systems and Documentation

The Operational Guidelines provided by UNESCO are a guide for the implementation of the Convention and represent a tool with guidelines for the management of World Heritage sites. In this document, the following is reported: "appropriate management plan" that each (candidate) site should have. The purpose of such a management system is to ensure the adequate protection of the designated property by maintaining all aspects of its Outstanding Universal Value.

The management system presented is a generic description and its variability due to the different characteristics and needs of the designated site is highlighted. All sites have to respect some general aspects common to all the properties and some different elements due to variety of situations.

The guidelines propose the use of an impact assessment to evaluate the effect of development proposals on a property's OUV and emphasise that WH sites have a role in sustainable development, as long as this does not have negative repercussions on them [1].

2.2 Local Evolution and Development Dimension

Protecting heritage goes beyond the protected goods; buffer zones and wider settings are set up when necessary. In the management systems definition, we can find the *wider setting* [1]. The approach goes beyond the physical boundaries of the core zone and includes social and cultural practices, economic processes, and other intangible dimensions of heritage. Managing a wider setting is considered from the supporting-the-OUV point of view. Its maintenance can contribute to sustainable development involving -mutually-

(local) society (or heritage community) and (World) heritage [13]. The assumption that heritage places depend on their environment and vice versa leads stakeholders not to think about heritage management apart from development activities, social change, and planning. Instead, the broader impact of heritage in the territory emerges, involving multiple right-holders and stakeholders. The more extensive the sites are, the wider the impact occurs. World Heritage serial sites are, in this sense, the perfect example [2]. The wider vision implies a multiplicity of actors involved, hence objectives to be set in the management tools. Hence, the goal to pursue is the entire valorisation of the system, no longer just protection and conservation [14].

2.3 Monitoring Tools

The management plan is starting point for the management of the site. It is generally submitted at the same time as the candidature dossier, and, after incorporating the changes proposed by the Committee, it governs site management. A general monitoring plan addresses the management system's effectiveness [2].

Monitoring is the core of the plan in the World Heritage system. Monitoring mechanisms include: (i) the identification of monitoring indicators; (ii) reactive monitoring (for critical situations), given the presence of threats that could affect the designated property and the conservation status process; (iii) periodic reporting [1].

Periodic Reporting is a formal requirement of the World Heritage system. It is a self-reporting process that each State Party deliver to the UNESCO General Conference through the World Heritage Committee. These reports cover the legislative and administrative provisions and other actions taken by the State Party, including reports on the state of conservation of its sites inscribed on the World Heritage List [1]. Periodic reporting guarantees the effective long-term preservation of the inscribed sites. At the same time, it is also a valuable tool for site managers because it allows a periodic review of the management system's effectiveness. The monitoring system is mandatory for UNESCO and useful to the site itself. The question is whether the interest also concerns the wider territorial context. Among the tools suggested by UNESCO for evaluating the effectiveness and functioning of sites is the *Enhancing our Heritage toolkit 2.0.*

2.4 Enhancing Our Heritage Toolkit 2.0

"Do management processes influence conservation results"? [3].

This is the introduction to the *Enhancing our Heritage Toolkit 2.0*, a self-assessment model consisting of 12 tools that measures the effectiveness of managing World Heritage Sites. The model is a participatory process involving local, regional and national managers. The word *manager* refers to all involved actors, private and public, as responsible for the management of the entire or part of the site [3], as "Ideally, all those involved in the governance and management of the World Heritage property or other heritage place should take part in the management effectiveness assessment". The tools come with worksheets that can be adapted to each specific case. The toolkit supports site managers in revising their management practices [3]. The tool is proposed as a generic guide, with a view to a specific declination linked to the characterisation of each site [4, 15].

Certain types of heritage places may require a more flexible use of the Toolkit. This is particularly the case for serial World Heritage properties. Here, you will need to decide how best to adapt the tools to your needs, the complexities of the property and the management system in place.

Part of the tools of the toolkit are examined below, in particular the three realated to the governance and the management system: tool4, tool 6 and tool 8.

Tool 4 Governance Arrangements
The tool goes into the responsibilities and tasks that each actor involved has in the management process. The clarity of the assigned roles and the effective collaboration and coordination between the actors are analysed. It also goes into the level of participation of stakeholders in the management of the World Heritage Site.

The tool consists of 3 worksheets: (1) identifies which actors can be considered managers and their specific roles (applicable division between managers with primary responsibilities and managers with responsibilities over limited areas of the whole site); (2) is about cooperation and coordination between managers, only in this sheet there are documents, agreements regulating how the different roles and responsibilities are distributed; and (3) about involvement in management by groups of right-holders.

Tool 6 Management Planning Framework
The tool investigates the adequacy of the management plan for effective property management. It identifies how effective the planned system is for the protection and management objective of the designated site (on the property, in the buffer zones and the wider context). In the in-depth study of its worksheets, the tool, also intends to prepare conclusions on the adequacy of the planning framework.

ITool 8 Management Processes
The tool reviews the adequacy of management processes, focusing on three core processes: decision making, planning and community engagement. The tool delves into how the management plan was developed.

The questions and issues that are asked in the different tools of the kit present a clear framework of the site, only when the answers about the management are available, but future proposals still need to be answered in the kit.

The EoH toolkit analysed lacks a specific part relating to the relationship between the heritage proper and its context. Hence the research question: when are management processes antifragile? Under what conditions and with what territorial impact?

The antifragile approach is presented as a possible guide to follow.

3 Antifragility Orientation

Questions about opportunities and recommendations remain open and are freely expressed by the compiler. In the following section we want to examine the issue of antifragility in relation to the management and monitoring systems of World Heritage Sites. Antifragility can be, declined in its principles, a path for site opportunities with regard to its management.

3.1 The Essence of Antifragility

The definition of antifragility [16] explores the differences between it and the concepts of robustness, fragility and resilience. The aspect that grants it differentiation is the potential gain caused by the intrusion of perturbing events into the phenomenon [9]. Something is antifragile in relation to a perturbing event, a stressor. According to Taleb (2012), in the case of the systems, depriving antifragile systems of the stressor factors they need produces great fragility. Its opposite is, therefore, optionality, having more possibilities, for that principle pragmatically described by Taleb according to which a single large stone thrown at someone is much more damaging than a thousand pebbles. The more variability there is in a system, the less that system is subject to Black Swans.

In the antifragile approach to complex systems such as those for managing heritage spread over a territory, the problem arises of measuring and quantifying the potential benefits this could contribute.

According to Blecic and Cecchini, the question remains "Antifragility of what to what?". In the management of the systems of World Heritage, in order to answer the question, an additional dimension useful in evaluation must be given: time. Unesco offers monitoring tools useful for making a periodic evaluation, in a long time-line, at certain moments in the life cycle - starting with the designation or in anticipation of it - of goods. This temporal dimension is fundamental in evaluation. To use Taleb's words, on a functional level, time is analogous to volatility because more time translates into more events, and more disorder. Thus, evaluation can be performed as time goes by, allowing mistakes to be made, disruptions to be acknowledged, and subsequent positive responses to these. Such antifragility is obtained because the system incorporates learning mechanisms in this way [10].

The answer can be structured around the question: can management policies learn from themselves? And, more specifically, how is this learning process measured? One answer lies in the governing instruments that regulate and regulate the policies themselves. Hence, the antifragility of the instruments of governance and regulation for heritage management. The answer given intends to pursue both issues that Blecic and Cecchini (2019 and [17]) suggest should not be separated: the construction of a system -in this case of management- that makes the heritage antifragile and that is antifragile itself.

3.2 Antifragility in Planning

According to Blecic and Cecchini, antifragile planning is structured around some principles. They are listed below: (1) modular design, which through the identification of the minimum unit of intervention in which to act in the model proposal so that even if something is fragile in the individual part, the entire system is not affected; (2) decentralisation through layering, in favour of discretionary action in the various institutional levels; (3) redundancy, in favour of a trial-and-error system that allows for mistakes to be made quickly, without irreversibly damaging the system and with a reaction time that can be reasonably assimilated by the entire system; (4) resist the urge to suppress randomness, for an openness to the possibility of accepting unexpected opportunities that can benefit the entire system; (5) skin in the game, in favour of proactivity on the part

of decision-makers in planning processes that can favour adaptable, non-rigid planning; (6) Chesterton's Fence, a principle based on the assumption that conflicts linked to the multiplicity of actors in the system must be able to exist in a dynamic, albeit precarious, equilibrium; (7) optionality, as the property of having different possibilities, options, without constraints.

4 New Governance System for the World Heritage Site *City of Vicenza and Palladian Villas of the Veneto*

Finally, the ongoing project of the WH Site City of Vicenza and the Palladian Villas of the Veneto is presented and discussed. The site is, at the time this contribution is written, in the updating process of its management plan, reviewing its governance and management structure.

4.1 Case Study

The serial site involves different institutional, public, and private subjects and represents a highly diffuse reality closely connected to the regional territory [12]. The site consists of 25 components: the city of Vicenza (which includes the historic center with its 23 Palladian monuments) and 24 Palladian villas spread over the region, in the provinces of Vicenza, Padua, Rovigo, Treviso, Venice and Verona. All the subjects directly involved in the heritage management are 21 local authorities, 6 provinces, the Suprintendence of architectural and landscape heritage, the Superintendence of archaeological heritage, the Veneto Region, the Cultural and landscape heritage Regional Direction, Vicenza Diocese, Regional Institute of Venetian Villas (IRVV), Regional Association of Venetian Villas, CISA Palladio.

The diffusion over a culturally homogeneous territory of a heritage with a public and meritorious character and the consequent copresence of different institutional subjects, public and private [12] and the request of UNESCO made to each site on the List, led in 2007 to the first management plan still in force at the time of writing. The property's Management Plan was developed by several public and private Institutions. There is a UNESCO office, set up inside the Municipality of Vicenza, which is the referent of the Site and takes care of technical and administrative aspects and is charged with the monitoring of the property's Management Plan. In addition, there is a piloting committee responsible for the proper functioning of the plan (Table 1).

Since the ICOMOS/UNESCO Advisory Mission concluded in 2017, the site is on observation by the Committee (ICOMOS UNESCO, 2017). In the Advisory Mission Report, it is noted that the role of the site Manager to the City of Vicenza (UNESCO Office of the Municipality) should be reconsidered, and the function should have more support. Difficulties in the governance system emerge especially in relation to a poor capacity for involvement of the different subjects involved.

The report advocates for a more direct involvement of the province, as well as the Ministry of Cultural Heritage and Activities and Tourism (today Ministry of Culture), in the role that its peripheral offices play at the regional level (MIBACT Recommendation 19). Additionally, the factual functioning and role of the piloting committee, which met

Table 1. Governance system of the current Management system

Organization/body	Role within the site	Functions
"UNESCO Office" within the Municipality of Vicenza	Referent subject for the entire World Heritage Site	Operational structure of the site with secretarial functions and monitoring of the management plan
(1) Veneto Region (2) Regional Direction for Cultural and Environmental Heritage of the Veneto	General coordination	(1) Legislative, planning and programming functions; (2) Protection of cultural heritage
Province of Vicenza	Coordination of the provincial and municipal administrations involved in the site	Acquisition and organisation of all the documentary and cognitive elements for the extension of the Vicenza City Management Plan to the Villas
Municipality of Vicenza; Province of Vicenza; Veneto Region; Vicenza Diocese; Regional Directorate for Cultural and Environmental Heritage of the Veneto Region; Suprintendences of Veneto; International Study Center on Andrea Palladio; Regional Institute of Venetian Villas; Regional Association for the venetian villas; Municipalities of the Provinces of Veneto; Marketing, administration and tourism experts	Piloting committee	Coordinating and reviewing the implementation of the management plan

more than a decade after its creation in 2005, is questioned. It is suggested that its composition and functioning be rethought.

In 2023, the UNESCO office of the Municipality of Vicenza, began a process of revision of the area with the aim of drawing up the Periodic Report and updating the Management Plan. For this task, the Municipality of Vicenza collaborated with an external project manager who is an expert in guiding UNESCO sites, as well as two companies that are specialists in documenting and producing materials for cultural and heritage sites and activities related to territorial development. The group's initial considerations focused on studying the current management plan. This led to the identification of several key issues that should not be overlooked during the revision phase:

(i) the significance of the site to institutional actors and private owners and managers involved in the heritage;
(ii) the presence of collaborative networks among some of the owners or managers for shared use of the site's goods. This could potentially lead to similar initiatives among other components of the site;
(iii) the presence of a UNESCO office within the organisational structure of the Municipality of Vicenza, with the role of reference point for the site, is a valuable element. It offers a single point where best practices and identified criticalities can be collected;
(iv) the previous management plan was not effectively implemented despite agreements;
(v) the lack of operational coordination among public actors has resulted in a fragmented development of coordinated initiatives on the site as a whole. Additionally, there has been a lack of management of collaboration between public and private actors involved. Finally, an authoritative direction in the management of the serial site has been absent;
(vi) there is a lack of uniformity in service standards, which is a result of the higher management level's failure to reach an agreement with all private stakeholders.

4.2 Ongoing Proposal

The Management Plan under review must receive formal approval from all those with management responsibilities, as well as from the private owners of the heritage, in order to create a stable network in which the commitments, responsibilities and opportunities that come with the UNESCO designation are shared. After a year of discussions with various institutions and stakeholders, the task group proposes the association model as a possible solution, considering the complexity of the site and the large number of parties involved. An association could enable the differentiation of contributions and skills among members based on their belonging to different typologies. Specific prerogatives may be reserved for those identified as founding members. If an association is formed, it will be necessary to initiate a series of activities and to respect the democratic and participatory dynamics inherent to an associative body, with regular and permanent meetings of the management committees and the possibility of having a structure adapted to the needs expressed by the territory and the local actors, as well as identifying mechanisms for listening to needs and balancing legitimate divergent interests.

A new assessment model is now proposed. It integrates the principles of antifragility and some of the existing Enhancing our Heritage toolkit (Table 2).

4.3 Principles of Antifragility

The current analysis examines the application of the principles of antifragility to the management of the whole site through the hypothesis of an association and its statute. The statute we thoroughly examined has not yet been adopted by the managers of the site.

Modular Design and Decentralization Through Layering

The initial two components of antifragility, modular design and decentralisation through layering, are to some extent structural, independent of the management system adopted,

Table 2. Integrated assessment tool combining Enhancing our Heritage toolkit and principles of antifragility

Enhancing our Heritage toolkit	
Tool + worwsheet	**title**
4a	Assessment of roles and responsibilities of managers
4b	Assessment of coordination and collaboration between managers
6a	Assessment of management planning framework
6b	Assessment of primary planning instrument
8b	Assessment of other important processes
Antifragility principles	
principles	**How the principle is being taken into account in management tools**
1. Modular design and decentralization; 2. Redundancy; 3. Resist the urge to suppress randomness; 4. Skin-in-the-game; 5. Chesterton's fence; 6. Optionality	

but rather inherent to the very character of the designated heritage. The site's seriality and subdivision into multiple modules make the management dimension of the site necessarily a modular one, to be applied to each part, with the possibility (and hope) that what has been planned will not work in some components and that this will allow the others to learn, to function differently, to be corrected (proof of concept approach).

The statute clearly outlines two principles: the establishment of a main office in the Municipality of Vicenza and the possibility of creating secondary offices, branches, or administrative and representative offices in the regional territory.

Redundancy

If one component fails, another can take over its role. The mechanism should be developed so that it can function in the event of a local failure. Redundancy must be built both vertically and horizontally [9]. In this case, it is particularly necessary to apply this principle to components in critical states of conservation, which represent a real risk to the maintenance of the OUV and put the entire World Heritage Site at risk. In such cases, overcompensation may be necessary, mobilising various actors (institutional, private, managers, associations) to take concrete action in place of the actor(s) responsible for maintaining the site's attributes. Intervention through overcompensation, with the participation of multiple parties in managing the most critical components for preservation, can mitigate the risk of adding to the list of endangered world heritage sites. This approach also provides an opportunity for the involved parties to collaborate on actions for protecting the territory.

Resist the Urge to Suppress Randomness
This principle is in direct opposition to the rigid Weberian management model of 'putting the screws in' [12]. The current non-controlled management system has already experimented with this free modality, which has allowed in several cases the operators to proceed with a beneficial self-organisation, even if isolated from the World Heritage system. Currently, some models of proactivity can be considered in the implementation of "self-organisation" zones within the management tools under construction.

Skin-in-the-Game
The management system has demonstrated that the piloting committee's designation, based on a protocol of agreement signed by all the active actors, has not been able to effectively carry out the tasks set and the roles assigned. The proposal to set up an association to guide the management of the site and the definition of the various social bodies represent an opportunity to mobilise all the actors involved and to support their pro-activity in the system, which, with the contribution of different actors with different instances, can lead to an effective and adaptable policy design (Blecic Cecchini, 2023) and to the implementation of a governance logic that works in such a way that the governance body creates the conditions for the different actors to decide on their own to contribute to the goals [18].

Chesterton's Fence
The absence of an identifiable and effective governance system in the decades since the system was structured only on paper has allowed for self-organisation by all those involved as owners and/or managers of the components. This self-organisation, rather than being discouraged, should be taken into account and integrated into the new organisational framework. The system, following an antifragile management approach, would incorporate unofficial tools into a broader framework that adopts the most effective solutions already in place. It would modify and model itself based on what has been specified and deemed useful. It is possible to establish a logical governance framework by mobilising various actors to derive solutions from a network of collaboration.

Optionality
The proposed new governance system does not respect the principle of optionality. There are no different options available to the various parties. The instrument only offers one possible governance structure after an open sharing between all subjects, without any option for participation by the different private subjects. The level of private ownership remains on the fringes of total management, despite being included in a more structured way than in the previous site management cycle. The way in which the different subjects are treated has not been diversified on the basis of the different needs and conditions that each individual owner may have (Table 3).

4.4 Integrated Tool Applied to the Case Study

We propose the integrated assessment tool applied to the case study.

Table 3. Integrated assessment grid: application to the case study

Enhancing our Heritage toolkit 2.0 - tools				
Tool number of the toolkit	Worksheet	Title of the tool		
4	a	Assessment of roles and responsabilities of managers		
Group or institution recognized as managers	Specific role	Key instruments and powers at the managers disposal to implement mandate		Extent of involvement in the decision-making processes
x	x	x		x
4	b	Assessment of coordination and collaboration between managers		
Aspects/themes			Strenghths	Challenges
Existence of platforms, agreements, contracts, procedures and financial resources for coordination and collaboration			x	x
Sharing of relevant information between managers			x	x
Alignment for policies and plans			x	x
Coordination - ability to work together in a planned and organized way			x	x
Collaboration - ability to work together based on shared objectives, joint projects and planning and monitoring mechanisms			x	x
6	a	Assessment of management planning framework		
Name of plan	Territorial scope of plan	Level of approval	Year of last review	Year of finalizing instrument
Management plan 2024–2030	Guarantees the preservation of the Outstanding Universal Value accorded to the site for present and future generations	Strategic and operational document, in the process of approval	2024	2030
6	b	Assessement of primary planning instrument		
Name of planning instrument: *Management plan (2024–2030)*				

(*continued*)

Table 3. (*continued*)

Questions			Response
Legislative, statutory and other requirements			x
Planning context and integration with other planning instruments			x
Presentation and content of the plan			x
Resources, commitment and implementation capacity			x
Monitoring and review			x
8	b	Assessment of other important processes	
Questions			Response
Organizational			x
Communication, education and interpretation			x
Impact assessment, risk management and climate change mitigation and adaptation			x
Access, tourism and visitation			x
Research			x
Antifragility planning - principles			
principle		Response if the principle is present in the proposed management system	
Modular design and decentralization through layering		Establishment of a main coordination office in the Municipality of Vicenza, with the possibility of setting up secondary offices in the regional territory to act as intermediaries between right-holders and site managers	
Redundancy		Shared responsabilities, both financial and for maintenance of the OUV, by both private and institutional actors	
Resist the urge to suppress randomness		The new management system will maintain the existing forms of self-management and protection. These are the result of the lack of management in recent years	
Skin-in-the-game		Different groups of actors, with specific roles assigned, ensure that all actors are mobilised and encouraged to be proactive	
Chesterton's fence		The new system would incorporate unofficial tools into the management framework. These tools are actually effective ways to manage the property using solution already in place and already tested	
Optionality		Absent	

The tool developed here, which aims to analyse management practices and tools using the worksheets proposed by UNESCO and integrating them with the principles of antifragility, actually provides a complete reading of the management system. While

the existing worksheets analyses all the technical features of the management system, the antifragility principles explore how they work or do not work in practice.

Unlike the Toolkit questions, which leave many answers open for comment and observation, the antifragile principles provide a tighter guide to the assessment of the management plan.

5 Conclusions

The proposed assessment tool integrates existing models developed by UNESCO to assess the state of the art of site management issues and guidelines to guide antifragile policy planning.

The integrated tool makes it possible to obtain an evaluation of the heritage site by providing two categories of elements: (1) aspects related to the functioning of the management at the time of the evaluation, from the actors involved, to the coordination mechanisms, to the strategic planning tools; and (2) the analysis of the management tools regarding their possible functioning in terms of antifragility.

The proposed model, as applied to the case study of the World Heritage City of Vicenza and the Palladian Villas of the Veneto, shows how the different approaches integrated here are complementary. In fact, the responses to the Enhancing our Heritage Toolkit worksheets are not redundant with the antifragility-oriented evaluation part. On the other hand, there is a significant limitation in the evaluation section linked to the principles of antifragile planning. In fact, it is very unstructured and leaves the answers open in the evaluation. The less structured nature of this section is not in line with the Enhancing our Heritage toolkit's own evaluation forms.

The results discussed following this first application of the model suggest several developments. Firstly, the integration of assessment systems is a possible way to achieve a wider assessment tool than the existing Enhancing our Heritage toolkit alone. The second relates to future developments in operational terms and concerns the need to consolidate the model, in particular by substantially deepening and specialising the evaluation tool around the principles of antifragility. In fact, this part of the evaluation should be more tightly structured so that it is structurally homogeneous with the existing tools provided by UNESCO.

The final discussion presents aspects that can contribute to the development of governance tools that are antifragile and can enhance the antifragile management of World Heritage properties. The goal is to maintain the Outstanding Universal Value as declared by the Convention, by adopting the appropriate approach of antifragility. Antifragile orientation as a policy objective can be seen as one of the ways of achieving a wider benefit, which may include what lies beyond the boundaries of the core zones. The World Heritage framework is potentially open to critical debate here, as the anti-fragile nature of the system as a whole can cause local fragility [9]. The decision to adopt a planning orientation to management policy, however, raises the question of whether antifragile planning principles can be proactively incorporated into the cyclical review phase of the site, in parallel with the periodic reporting and monitoring system required by UNESCO. This approach would enable a more antifragile examination of World Heritage sites, extending beyond established boundaries and promoting a higher level of impact on the territory.

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A Methodological Approach for Activate a Community-Based Archive as a Decision-Support System in Urban Regeneration Processes

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Abstract. The community archive can be a powerful tool for territorial investigation and simultaneously a collaborative approach to learn and act in social innovation and urban regeneration processes. This study presents a methodological advancement for defining a community-based archive based on participatory mutual learning between experts and community inhabitants, aimed at co-identifying shared values by the context's spatial, social, cultural and environmental dimensions. If, on the one hand, non-formal training experiences represent an opportunity to re-understand the territory together through community engagement and empowerment actions, on the other, they produce data and tools that become interfaces to interact with in the decision-making processes that the archive is constantly called upon to define. The Atena Archive project, in the village of Atena Lucana in the province of Salerno, Italy, represents the context in which the methodological advancement was structured and applied in some parts.

The research, therefore, aims to examine the role of the community archive in territorial transformative processes, structure a value-centred approach for activating a community archive, and identify the decision-making processes to active during the census processes to make communities protagonists choose what to archive collaboratively.

Keywords: Community-based archive · participatory mutual learning · collaborative decision-support system

1 Introduction

Recent literature has shown an increasing focus on building community archives in different forms, including national collections, official registries, libraries, museums, business archives, internet platforms, and personal memories. Despite their variety, all archives share the characteristic of asserting themselves as authoritative sources by collecting, organising, and interpreting significant records. Archives curate a historical narrative by choosing and safeguarding elements from the past, trying to provide an accurate and unbiased account of history to society, and emphasising its roots, identity, and future trajectory.

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The assumed objectivity and authority of archive accounts have been questioned following the critique that arose in the 1990s. According to McKemmish [1], archives are dynamic entities built by authority that are not objective or impartial. Their narratives are shaped by choices over which components to incorporate, maintain, or omit, underscoring their storytelling power's subjective and discerning aspect [2].

In this sense, the city is also an archive because the urban fabric is a sedimentation of the past that can be richly evocative of memories that can destabilise the present by giving disturbing hints of other possible worlds that have existed and can be made to exist in the same urban and shared space. The space can provide the means to develop and experience shared collective memories to stimulate critical thinking and action. At the same time, community archives reflect a historical practice of recording local history and social movements by volunteers and activists [3].

A burgeoning collection of community archives literature currently focuses on particular organisations, localities, and issues [4]. Various political, social, and technological variables have led to the growth of independent archiving projects [5–7] that include the community in co-creating collective memory and identity in a digital environment [8–10]. Flinn et al. [11] define a community archive as the product of the community - represented by all kinds of people who come together - for their attempt to document the history of their territories and their identity, collecting material over which they exercise some control and over which they have substantial knowledge. Community archives can serve as substitutes for traditional repositories, and they can represent a method allowing communities to determine what is valuable to them collectively, shape their shared memory of the past, and manage how narratives about their history are created so they take control of the decision-making process [12, 13]. Anne Gilliland's VIA (Voice, Identity, Activism) framework integrates insights from many community archives projects to comprehensively establish a values-driven method for addressing these initiatives. Gilliland argues that a community-based archive practice approach prioritises a community's interests, needs, and well-being [14]. In fact, in the last decade, the most recent literature has introduced the concept of the 'participatory turn', according to which the involvement of communities in the identification, knowledge, protection and valorisation of tangible and intangible heritage is an indispensable practice to foster the regeneration of places and valorisation of identities.

In this logic, community participation is seen as an enrichment tool for traditional archives [15], as community members are invited to interact more actively with institutions and participate in managing and describing archives. This paradigm shift is identified with the term community-based participatory archives.

The concept of participatory archives is rooted in postmodernism, which values the user's role as a social agent in creating and managing collective archival memory. In literature, community-based participatory archives are combined with community archives. Nevertheless, studies and research are emerging that focus on community-based participatory archival projects, as the sharing of information and content between community members and decision-makers leads to a mutual understanding that results in a unique archive that is created with and for the community. Interpreting and creating the archive is shared with a broader public [16], correcting the gaps in content collection in many traditional archives.

Community-based participatory archives are a new approach in which archivists, land professionals, institutions and community members work together to document local histories and create distinctive archival collections.

Many participatory archives range from independent community-led efforts to institution-supported projects. Through these archives, community members support the collection of information and content that constitutes the territorial capital of a place, adding to the documentation all that represents value to them (personal experiences, memories of places, traditional activities, relationships and movements in community living spaces) and bridging the gap between personal and community aspects, as they help in the search for all those tangible and intangible elements and objects that need to be considered in order to tell the story of their territory and to identify the distinctive elements on which to build regenerative practices and processes. This knowledge makes it possible to build tools to support the territorial decisions of authorities and institutions.

As part of the process of evaluating what should be archived, Shilton [16] states that cooperation and collaboration between communities and archiving professionals generate mutual learning that leads to the knowledge and identification of those values that are to be recognised as representative of a community narrative and that constitute a narrative and interpretation of the spatial context other than a simple document. Successful decisions about what to value, as meaningful for the definition of a community archive, are based on understanding the value of particular narratives, documents or events that can only be recognised through mutual learning between those who archive and those who propose what to archive.

The concept of mutual learning, introduced by Scholz as a fundamental principle of Transdisciplinary (Td) research [17, 18], is defined as "the basic process of exchange, generation, and integration of existing or developing knowledge across different parts of science and society". In particular, mutual learning is based on the idea that people can learn more together than alone.

Mutual learning is regarded as a helpful approach in decision-making contexts as a knowledge-based support tool among experts and communities [19, 20], especially for investigating and exploring uncertain issues, as it manages to transcend mere knowledge acquisition [21]. The knowledge possessed by each community member enhances reciprocal learning, improving the forms of knowledge related to the territorial context under investigation. Mutual learning extends well beyond the mere exchange, generation, and integration of knowledge. Mutual learning creates the ideal conditions for the local community, experts and authority to share knowledge and good practices on a peer-to-peer basis to improve decision-making through a creative and collaborative approach[22], with the ability to integrate knowledge and experiences from various settings to reach a consensus on the transformations needed to achieve future strategies for the cities.

To gain "in-depth knowledge" on how to value community records, it is necessary to use participatory processes aimed at identifying those value elements represented for the definition of a community-based archive defined by and for the community.

Participants in community participatory archives support through their knowledge, a mutual learning mechanism thus established between community members, institutions, and all stakeholders [23].

From this viewpoint, documentation transitions from static document storage to a collaborative and evolving design process. The community-based archive anticipates collective memory by eliciting value rather than just being a repository of past events. It becomes a tool for rethinking and regenerating territories through recognising values [24].

This research is embedded within the framework agreement with the Municipality of Atena Lucana and the "Archivio Atena" project, winner of the public notice "Attractiveness of Villages", part of the National Recovery and Resilience Plan (PNRR M1C3) financed by the Next Generation EU. The objective is to construct a community-based archive for the Municipality of Atena Lucana. This initiative involves a broad spectrum of institutional subjects, local actors, and other figures (such as residents, students, artists, business enterprises, territorial associations, and census operators).

From this perspective, the research presents itself as a methodological advancement in a previous study [24], aiming to elucidate the role that community-based archives can play within decision-making processes in vulnerable inland areas [25].

It seeks to answer the following research questions:

- Is it possible to define the community-based archive as a value-centred tool to support decisions in urban transformation processes by generating new values from those recognised in census processes?
- How and with which method?
- Can mutual learning experiences become the approach through which a community-based archive is structured?

The research is structured into four parts: the first part is dedicated to introducing and contextualising the research questions within a broader international literary panorama. The second part concerns the methodological proposal, where the methodological approach is elicited. The third part deals with the methodological application of the case study. Finally, the fourth part gathers the discussions and conclusions.

2 Methodological Proposal

This paper proposes to advance the methodological approach outlined in the paper 'Community Archive as Place-Based Decision-Making Process: A Proposal for the Archivio Atena' [24] to answer the research questions. The previous experience attempted to outline a model approach to activating a community archive as a support tool in urban regeneration. However, in this advancement, the focus is on recognising the role of the community-based archive within decision-making processes. Specifically, the aim is to identify how the community-based archive can be considered a tool and an approach to activating mission-oriented and value-centred processes.

The methodological proposal, represented in a radial diagram (see Fig. 1), envisages two main conditions that stimulate census actions in a community-based archive: internal and external. In the first case, the community-based archive identifies objectives, timeframes and archiving processes through research-action paths as a territorial socio-cultural organisation and structure. In the second case, the community-based archive is

interrogated by an external decision-making environment (public administration, associations, agencies, etc.) so that the value capital recorded by the archive can support and guide choices at the urban level in response to a specific objective.

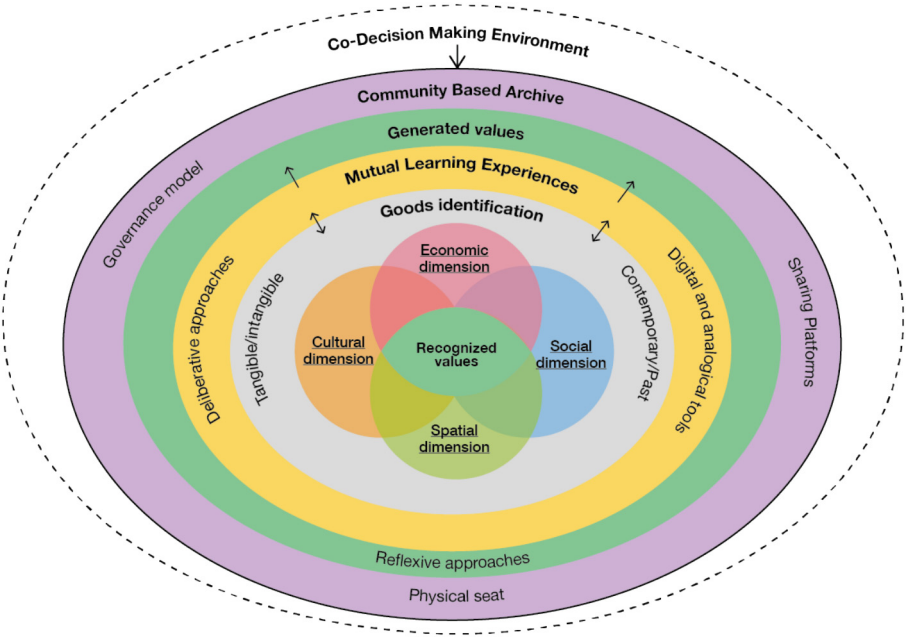

Fig. 1. The methodological approach proposed for a community-based archive

Starting from the literary background analysed, the Mutual Learning experiences (which can be translated, by way of example, into higher education schools, workshops, summer schools, etc.), due to their ability to relate communities of inhabitants and experts, are experienced precisely as operational expedients to co-identify existing values in the context and, at the same time, to co-generate new shared ones. Assuming the role of a hinge, shared learning activities thus represent the operational core of the community-based archive by using a set of deliberative approaches on the one hand and analogue-digital tools on the other.

By deliberative approaches, we mean those approaches that consider the collective and intersubjective meanings that, through social interactions, convey conceptions of the common good among people [26–29]. These approaches also allow for shifts from an individual to a social position, thus helping to identify common ground and reduce the polarisation of viewpoints that often characterise conflict situations. Therefore, deliberative methods can also promote learning and reflection. They encourage people to go beyond their self-interest to construct collective judgements that reflect a more comprehensive and socially just evaluation of public goods. The scientific literature divides these techniques into deliberative, analytic-deliberative, potentially-interpretive deliberative, interpretive, psychometric-deliberative and psychometric [30, 31].

The mentioned techniques can be considered part of the more extensive set of methods for evaluating Ecosystem Services. These methods can be grouped into two categories: those based on revealed preferences, such as direct observation, documentation, media and social media analysis, and those related to stated preferences [32], which include interviews, questionnaires, storytelling, participatory mapping, and focus groups.

Digital or analogue tools are all those devices through which value is identified within the mutual learning paths, and data is censored. These tools include apps, postcards, photographs, video interviews, and augmented reality. Each context, community archive, and census line is unique and requires a specific mutual learning experience and deliberative approach for tangible or intangible assets. Therefore, the tool used for a particular objective of census is determined by the communities participating in the mutual learning experiences.

Starting from the assumption that the community-based archive is conceptually structured on the shared identification of the values that communities consider relevant to the census in the exercise of self-representation [14–16], the methodological proposal pays attention not only to how these are elicited through collaborative modes and specific tools but also in which dimensions these values can be ascribed. At this stage, three main issues are important: the nature of the heritage recognised as a value, the temporal dimension in which contextual values are recognised, and the multidimensionality that characterises values.

In identifying the object of the census as heritage recognised or in the process of being recognised, it is necessary to consider, especially in the context of urban regeneration processes, that the consistency of the object of the census can be both tangible and intangible. According to the UNESCO definition, heritage is defined as the set of physical artefacts and intangible attributes of a group or society inherited from past generations, maintained in the present, and passed on for the benefit of future generations. In this sense, tangible and intangible heritage represents an expression of the communities residing in the territory. Specifically, intangible cultural heritage is manifested through oral traditions and expressions, performing arts, social customs, ritual and festive events, knowledge and practices relating to nature and the universe, and traditional crafts.

Therefore, it is important to remember that the co-identification of a community-based archive's heritage occurs in both the past and the present. This is necessary because the community-based archive is an ongoing process consolidating past memories and recognising the value of heritage representing contemporary times. The archive observes the context and its contemporary phenomena, which can outline future perspectives in the decision-making process.

Finally, the methodological proposal places the recognition of shared values central in the co-identification of tangible or intangible assets to be archived. Thinking "for values" [33], this approach recognises the census object as a representative medium of deeper values rooted in those relationships between communities and places. Therefore, a multidimensional approach is necessary to structure the process of recognising values potentially related to social, cultural, environmental, and economic dimensions. While exploring and assessing economic and ecological values has reached a precise scientific definition, it is far more complex to understand the vast and intricate set of values

that interact in the social and cultural spheres [34]. These values present divergences among themselves, yet spaces of hybridisation and interpenetration. Cultural values are inherited values that form the core of the cultural dimension, including customs, rituals and conventions that influence the tendencies, skills, and habits that characterise how people live [35]. Harrison and Huntington [36] go so far as to argue that cultural values are the things that matter in shaping economic progress, pointing to a close connection between cultural and economic value, understanding the latter almost as an externality of the former, for Throsby [37] cultural value' refers to the value created by cultural goods and experiences that is not merely 'economic value', tending to separate the two dimensions. An accepted conceptual basis to proceed is to extend the field of influence of cultural value, interpreting it as a composition of observable elements or dimensions (aesthetic value, symbolic value, architectural value, etc.) that may be susceptible to more specific evaluation [37].

Klamer, however, argues at the same time that cultural value is also separate from social value [31], which instead has its dimension, neither economic nor cultural. Pursuing the theory of relational sociology [32], one assumes the definition of the 'relational' nature of the person, i.e. the belief that the relationship with the other constitutes individuality. From this perspective, social values are considered to be those that strengthen human relationships through the practice of respect, justice, and freedom, for example, in seeking a better future. Therefore, social values can be defined as transcendental and understood as part of the social change expected by the people in a community. In this direction, no social value acts independently, as together, they form a chain of values that, exercised repeatedly, release positive results. It is evident, therefore, how recognised values are hardly ascribable to one of the four dimensions but rather to a more complex overlapping of different dimensions that contribute to delineating values and, thus, recognisable assets.

While mutual learning experiences are, therefore, functional in eliciting values, they also become strategic in generating new ones through re-recognition through the relationships and exchanges between communities and experts. The new values, hybrid in their overlap, can manifest themselves in new skills, entrepreneurial perspectives, urban processes, uses, and economies. By way of example only, we mean new values generated, visible through the outputs produced by the census lines (e.g. video-interviews, magazines, publications, exhibitions, web platforms, etc.), social values (e.g. human relations, professional relations, etc.), cultural values (e.g. new projects, new knowledge, etc.), economic values (e.g. new trades, new economic chains, new recognised organisational forms, etc.), environmental values (e.g. new guidelines, new regulatory approaches, new urban transformations, etc.). Newly generated values also mean new futuristic perspectives that a community-based archive is thus able to offer, through its interface, to the decision-maker questioning it from the outside. Recognising the new values generated is important for promoting dialogue and reflection. This dialogue allows communities to re-examine what has been done, the emerging values, and prospects for the future. If learning is considered a 'transformation of experience' [39], this requires skills of reflection, deliberation and evaluation that must be learned [40] to build new forms of cohesive communities around shared values.

The new values generated, together with the recognised values, thus represent the base of an iceberg at the visible apex of which appears, in the chosen platforms, the products of the census carried out (digital or not) and the new value heritages generated; the physical space in which the archive may decide to configure itself; the organisation that governs the archive through its governance model and structure. The combination of these three dimensions externally characterises the community-based archive as a complex tool with which the external decision-making environment can interface to develop processes of valorisation and regeneration of the spatial context in which the community archive operates.

3 Case Study

3.1 The Contest

The case study takes place in Atena Lucana, a municipality in southern Italy with a population of 2,430. Atena Lucana is one of the 15 villages in the Vallo di Diano area, in the Salerno, Campania Region province, which falls under the 'internal areas' category. The town, on the border with Basilicata, is situated on a hill in the western part of the valley at an altitude of 625 m above sea level (see Fig. 2). Access to the Vallo appears to be significantly facilitated by the nearby and modernised Salerno-Reggio Calabria motorway. However, the historic centre of Atena Lucana, of medieval origin, situated on the top of the hill, is currently abandoned. It is built around three concentric rings connected by small streets and ramps that are not easily accessible. Most of the inhabitants of the historic centre have moved to newly built areas.

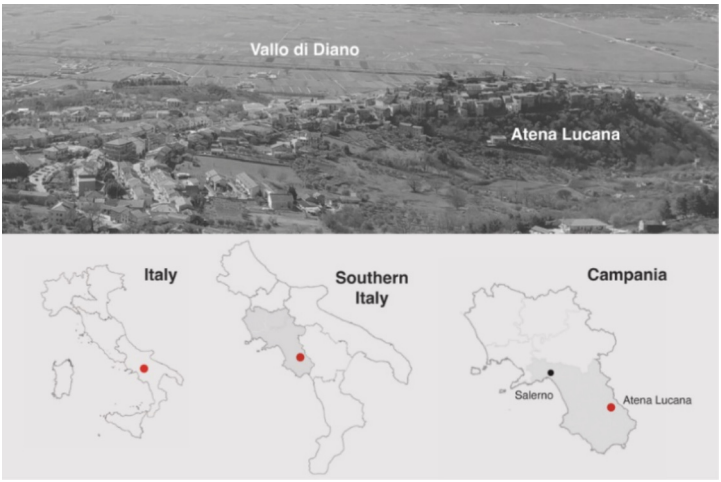

Fig. 2. Atena Lucana

Thanks to the allocation of the Ministerial Grant for the Attraction of Historic Villages, the creation of a Community Archive called "Archivio Atena" is in full swing.

The project involves digitising the cultural heritage and creating a permanent laboratory for the meeting of researchers, scientists, artists, cultural operators, and public and private institutions to develop new ways of narrating the territory through the identification of spatial, cultural and social values. The Community Archive aims to collect a community's local cultural heritage, both material and immaterial, to preserve and promote its shared identity.

The "Archivio Atena" is part of a broader research project called "Opera Paese", which aims to create a digital photographic archive in the Cilento Vallo di Diano and Alburni National Park (SA). "Opera Paese" is led by a group of researchers (photographers, art historians and experts in digital archives) who use photography as a research tool and consider the photographic archive as a means of preserving collective memory and promoting the territory. "Opera Paese" focuses on acquiring and sharing private photographs, activated through a participatory and collaborative collection. A simplified method for collecting, digitising and describing family photographs has been developed in collaboration with the Central Institute for Cataloguing and Documentation of the Ministry of Culture. This method was transferred to a local working group through a training process.

The Municipality of Atena Lucana, supported by the will of the associations present in the area, has expressed interest in adopting the practices of Opera Paese to initiate a cultural and urban regeneration involving the community and the space of the historic centre. Hence, the participation in the ministerial subsidy, resource allocation, and the birth of the "Archivio Atena" project.

In 2022, Atena Lucana will begin experimenting with a new method developed in collaboration with training institutes in the field of photography, such as ISIA in Urbino, university institutes, such as La Sapienza in Rome and Federico II in Naples, and ministerial bodies, such as ICCD, the Central Institute for Cataloguing and Documentation.

3.2 Mutual Learning Experience

This paper recounts the specific experience of the Mutual Learning School of Advanced Training conducted with La Sapienza University of Rome, which aimed at professionalisation in the processes of collection, organisation, digitisation, and description of private photography, aimed at the establishment and increase of community archives. The school is involved in the realisation of census projects by enhancing elements belonging to cultural heritage and their respective values. All the work carried out in this phase became part of the gradual process of composing the community archive.

The narrative of this case study attempts to demonstrate how the community archive feeds its census lines through an experience of Mutual Learning and how the archive can support community decisions. The students and inhabitants who participated in this training experience contributed to developing a thematic census in a bottom-up process of construction and restitution. The actively involved community members, those who came here on purpose, and external experts activated a collaborative process by exchanging knowledge, experiences, and diverse perspectives. Together, they determined the scope and contents of the archive.

The school encouraged an open and inclusive dialogue among all stakeholders. The students were divided into balanced working groups in terms of age, level of education, interests, and skills. Each group included at least one photographer and one resident.

The school was structured into modules, with some consisting of theoretical lessons and others of laboratory activities. During the laboratory, the students took exploratory walks identifying places and cultural values that trigger relationships. Thanks to urban and rural walks, collaborations with residents were activated. In a collaborative approach, several group brainstorming sessions, guided by teachers, were structured to formulate census themes. The investigation phase was important for defining a theme, during which interviews were conducted with the people involved.

The census project analysed in this paper stems from the shared idea of a group reflecting on the theme of dwelling, which implies observing and understanding habits and housing conditions. From the investigation conducted by the students in the field, it emerged that for the community of Atena Lucana, the kitchen has been and continues to be a central place for domestic life, a place of sharing not only within the family but also communal. The group of students under examination came into contact with the Pignata family, facilitated by the presence of a family member in the work team. The School of Advanced Training students and the extended family became the authors of a new census.

The Pignata family shared the old hearth of the house (see Fig. 3), perhaps the most intimate space and dimension of family life. The old kitchen became a place of learning, a research and action set. It was rearranged and reactivated to allow the preparation of a typical dish from the culinary tradition “Sciuscielli.”



Fig. 3. Pignata family kitchen

The material goods identified and censused during this research were the kitchen space composed of the hearth and the small furnace, both inserted in a structure of

bricks and mortar, lined with white tiles; a sizeable wooden pantry cupboard still used to store preserves, utensils, and ancient tools that make up the work surface (see Fig. 4). These were described and catalogued one by one according to parameters established with the archive expert from ICCD. The identified immaterial goods were the ancient recipes narrated, the stories, and the interviews. The analogue tools used were hand-drawn sketches made during site visits, which provide an overall image of the space and the transcription of recipes. Digital tools included photos of the kitchen space, the re-staged set, each catalogued utensil, and recordings of interviews.



Fig. 4. Census of tools and utensils

The census of these assets results from a deliberative approach because the identification of the census theme, the implementation methods, and the outcomes resulted from interaction among experts, students, and representatives of the local community.

From studying this space, strongly characterised by material and immaterial goods, research extends beyond the domestic walls through new forms of conviviality and sharing. The narrative of people, stories, practices, and memories takes shape through the study of individual objects, documentation, and photographic census. "Fire, Pignata, and Sciuscielli" becomes a participatory art action: every process, tool, technique, or culinary recipe is staged to be transmitted, safeguarding the heritage of the domestic hearth. The project found its restitution in a convivial moment that starts from the preparation of the dishes, reaches the consumption of the meal, and ends with the stories of the people. A community dinner that explores Atena Lucana in its traditions, discovering its gastronomic peculiarities, ancient customs, and narratives that will become part of the extensive Community-based Archive.Subsequently, a reflective phase opened in which the working group was encouraged to critically discuss the identified values' multidimensionality. Their cheerful and negative implications, possible conflicts or contradictions, and the challenges that could arise in repeating such an experience and promoting these values were examined.

4 Discussion and Conclusion

The research reflects on the role of community-based archives as a decision-support tool, particularly in urban and territorial transformations affecting vulnerable contexts in inland areas.

In the context of the case study of Archivio Atena, in the historical centre of the village of Atena Lucana, in southern Italy, it was observed how community-based archives have the capacity to go beyond the conventional role of preservation and instead act as platforms for the activation of communities in paths of civic participation. Cultural heritage and memory's tangible and intangible resources can shape future visions and urban policies. Creating a community cooperative to manage the community archive and collaborating between the public administration and the archive to regenerate an abandoned village is a good example.

The experimentation of approaches based on mutual learning to include local communities in creative processes of co-design and co-production with experts has proven to be particularly effective due to its ability to recognise shared values through experiences and, at the same time, generate new ones. The school of higher education, as well as workshops, residencies, and summer schools, prove to be compelling opportunities, especially for re-interpreting neglected contexts such as the historical centre of Athena. While the exchange of knowledge and expertise between locals and non-locals stimulates the sharing of memories and limits their loss, it also fosters the emergence of new ideas and projects. The intergenerational and shared recognition of social and cultural values, which are considered relevant and therefore to be preserved and passed on, often stimulates innovative processes for their re-interpretation, generating both new artefacts (crafts 3.0, design, etc.) and new cultural gimmicks (events, festivals, etc.) that can innovate traditions and develop new ones. The new projects linked to the theme of food and wine tourism, which emerged from the historic village kitchens census, manifest this.

At the same time, it is also necessary to recognise how the centrality of mutual learning experiences in the methodological framework of the community-based archive entails risks. While the sustainability of these experiences requires significant design efforts and expertise, mutual learning is not always easy to implement in local processes. This implies a constant interaction between participants, inhabitant communities, experts of different ages and backgrounds, and geographical contexts, which sometimes find weak spaces for mutual understanding. Moreover, the mistrust of the inhabitant communities can sometimes be a barrier to the success of mutual learning experiences structured in this way.

Moreover, the physical space in which the community-based archive is located, as well as the platforms for collecting and sharing the census materials, both digital and non-digital, become, in these processes, shared spaces of co-learning that are representative of the communities that inhabit them and also significant for external communities. To date, Archivio Atena is fuelled by the production of photographs by contemporary authors taken during residencies open to artists and scholars from different disciplines, capable of narrating the multidimensionality of recognised values from various points of view.

In conclusion, the research proposal consolidated in the practice of Archivio Atena provides a replicable approach and model for activating community-based archives as

effective and innovative decision-making tools within urban and human regeneration processes based on listening and participation of local communities.

For the future, it is crucial to continue exploring and implementing community-based archives in other contexts and to stimulate an evaluation of the multidimensional impacts they can generate on the communities they inhabit and the territories in which they operate.

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Author Index

A
Amini Alaoui, Kaoutare 171
Amrei, Seyed Ali Razavian 244

B
Barracco, Alessandro 184
Bayas, Marcia 44
Bernal Párraga, Augusto 18
Blečić, Ivan 406
Borlizzi, Patrizia 406
Bustamante, Carlos 3
Bustamante-Encina, Ruben 3

C
Campisi, Tiziana 141
Campuzano, Maria 44
Cannatella, Daniele 388
Cardaci, Alessio 153
Catania, Giulia Fernanda Grazia 89, 107
Cattaneo, Tiziano 273
Cattani, Chiara 309
Cerreta, Maria 356, 373
Coronado-Hernandez, Jairo R. 56
Costa, Giannina 56
Cuntò, Stefano 337

D
Dastranj, Radman 205
De la Torre, Jayli 71
De Lotto, Roberto 256
Duran-Riveros, Marcia 56

E
Esmaeilpour Zanjani, Nastaran 205, 244

F
Fazia, Celestina 89, 107, 141, 184
Felli, Annamaria 309
Figueroa, Junior 44
Fiorini, Lorena 323
Fuentealba, Diego 3

G
Gatica, Gustavo 3, 56
Giorgi, Emanuele 273
Girgibo, Nebiyu 291
Goodarzi, Ghazalhe 244
Grieco, Benedetta 373
Guisa, Donatella 323

H
Heris, Mehdi P. 226

I
Imbaquingo, Daisy 71

L
La Rocca, Ludovica 421
Lima, Naghmeh M. 205
Llumiquinga, Jaime 71
Loffredo, Caterina 421
Lopez, Felipe A. 3, 56
Lü, Xiaoshu 291

M
Maldonado-Duran, Sebastian 56
Marziali, Emilio 309
Mohammadpourlima, Naghmeh 226, 291
Muccio, Eugenio 337
Murgante, Beniamino 256

N
Nahiduzzaman, Kh Md 141
Nahiduzzaman, Kh. Md. 171
Ngan, Pham Le Song 31
Nikfarjam, Romina 205
Nygård, Mikael 226, 291

O
Oddo, Maurizio 184

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P
Pham-Quoc, Cuong 31
Pietra, Caterina 256
Pietrangeli, Sara 323
Poli, Giuliano 337
Portinaro, Alessandro 406

R
Radoine, Hassan 141, 171
Raiola, Maria Lucia 373
Rizzetto, Francesca 388
Román Cabrera, Jenniffer 18
Ruete, David 56

S
Sacco, Sabrina 373
Saganeiti, Lucia 323
Saliu, Maria Carla 406
Somma, Maria 373, 421
Sortino, Federica 107

T
Torres Illescas, Veronica 18

V
van der Waal, Max 388
Venco, Elisabetta Maria 256
Ventre, Sveva 356
Versaci, Antonella 153, 184
Vicari Aversa, Clara Stella 89, 123, 184
Villacrés Prieto, Priscila 18

Z
Zizzania, Piero 373
Zullo, Francesco 309