Lecture Notes in Networks and Systems 1186

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Networks, Markets & People

Communities, Institutions and Enterprises Towards Post-humanism Epistemologies and AI Challenges, Volume 4

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Preface

This volume contains the proceedings for the International Symposium "*NETWORKS, MARKETS & PEOPLE for transitioning settlement systems. Communities, Institutions and Enterprises towards post-humanism epistemologies and AI challenges—#NMP 2024*", scheduled from 22 to 24 May 2024, in Reggio Calabria, Italy.

The symposium was promoted by the European Cultural Heritage Enhancement Lab—ECHE Lab (former UNESCO Med Lab), Mediterranea University of Reggio Calabria (Italy), with ASTRI Scientific Association and the National Italian Committee of ICOMOS.

The Symposium is organized in partnership with: CETRAD, Centre for Transdisciplinary Development Studies, University of Trás-os-Montes e Alto Douro, Vila Real (Portugal); NEUROLAB, Mediterranea University of Reggio Calabria (Italy); GRUPO ANTE, University of Santiago de Compostela (Spain); LaborEM, Mediterranea University of Reggio Calabria (Italy)

The Symposium is mainly supported by a qualified network of scientific societies: SIEV—Società Italiana di Estimo e Valutazione; SIIV—Società Italiana Infrastrutture Viarie; AIIT—Associazione Italiana per l'Ingegneria del Traffico e dei Trasporti; SITdA—Società Italiana di Tecnologia dell'Architettura; AISRe—Associazione Italiana di Scienze Regionali; SISTur—Società Italiana di Scienze del Turismo; AGEI—Associazione dei Geografi Italiani.

NMP2024 aimed to promote the scientific debate about the effects that the contemporary environmental, technological, social and economic global challenges produce on settlement systems, especially in Inner Areas and metropolitan cities of the Mediterranean basin.

Contemporary settlements express the distance between the built environment inertia and the "liquid" society flowing underneath. Blurred lines substituted the neat dualities such as culture-nature, urban-rural, central-marginal, affluent-deprived, enacting perpetual changes in between polarities.

The progressive increase in population raises new issues connected with resources availability and the ecological footprint of anthropic activities.

The theme of the green transition requires multidisciplinary points of view, touching on very different issues such as infrastructures and mobility systems, green buildings and energy communities, ecosystem services and land consumption.

In this scenario, a post humanist epistemology assumes that humans are dependent on the environment, and part of a larger evolving ecosystem whose agency is distributed through dynamic forces. Climate change challenges reinforced the understanding that human is entangled with its environment, encouraging in defining novel epistemologies, including, but not limited to, several disciplines: architecture, urban studies, economics, cybernetics, ecology, ethology, geography, art, psychoanalysis, sociology, anthropology and quantum physics.

The new frontier of adaptive and flexible production, supported by the ongoing digital revolution, encourages a rethinking of the concepts of proximity and interdependence within human settlements, with a paradigm shift in the center-periphery dualism. In this context, the social reproduction approach is mainly oriented at spatial justice, re-use, regeneration and environmental care.

Digital technologies and artificial intelligence bring extraordinary potential to institutions, companies and social organisations, but also carry the risk of negative impacts of unmanaged innovation.

The Artificial Intelligence, challenging the labor market, has been seen lately as both the exploitation and the destruction of the human being as known until now. The progressive replacement of human workforce with machines no longer concerns the traditional industries only, affecting intellectual and creative productions.

The side effects of this transition need to be studied in order to share benefits and tradeoffs equitably between technology and service developers on the one hand, and individuals and communities on the other.

Accessibility rights to services and goods, social inclusion, commoning and sharing economies, as well as informalities and self-organization permeate the incoming social organization associated with the digital transition, towards inclusive concepts of citizenship.

Social innovation practices, collaborative governance models, open innovation frontiers, human non-human entanglements concur in setting the route for the next generation settlements, notably: the built environment, the social system and the complexity and challenges of the everyday life.

These phenomena are even more significant for marginalized areas, which are compelled to face the risk of widening the socio-economic gap with advanced regions, as happens in some territories of Mediterranean bordering countries.

Green and digital transition are the two pillars on which European policies are based for the period 2021–27, above all through the instrument of the Next Generation EU. The substantial investments planned by the EU to support the green and digital transition in the coming years require multidimensional evaluation systems, capable of supporting decision-makers in selecting the interventions most effective in pursuing the objectives, also considering that the financial resources used for the Policy implementation are borrowed from future generations, who will be held accountable for our work.

For this edition, meanwhile, the more than 300 articles received allowed us to develop 6 macro-topics, about "*Communities, Institutions and Enterprises towards post-humanism epistemologies and AI challenges*" as follow:

1. Cultural Heritage as driver of development for territories and tourism destinations
2. Ecosystems, people-nature cohesion and urban-rural relationships
3. Decision support systems for urban regeneration
4. Policies and practices of cohesion and social innovation for inclusive cities
5. Green buildings and sustainable solutions for ecological transition

and a Special Section, *Supersession intercluster SITdA*, chaired by our colleague Consuelo Nava.

We are pleased that the International Symposium NMP, thanks to its interdisciplinary character, stimulated growing interests and approvals from the scientific community, at the national and international levels.

We would like to take this opportunity to thank all who have contributed to the success of the International Symposium "*NETWORKS*, *MARKETS & PEOPLE for transitioning settlement systems. Communities*, *Institutions and Enterprises towards post-humanism epistemologies and AI challenges—#NMP 2024*": authors, keynote speakers, session chairs, referees, the scientific committee and the scientific partners, participants, student volunteers, and those ones that with different roles have contributed to the dissemination and the success of the Symposium; a special thank goes to the "Associazione ASTRI", particularly to Angela Viglianisi and Immacolata Lorè, together with Alessandro Rugolo, for technical and organisational support activities: without them the Symposium couldn't have place; and, obviously, we would like to thank the academic representatives of the University of Reggio Calabria too: the Rector Prof. Giuseppe Zimbalatti and the chief of PAU Department Prof. Tommaso Manfredi.

Thank you very much for your support.

Last but not least, we would like to thank Springer for the support in the conference proceedings publication.

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INTERNATIONAL SYMPOSIUM

Reggio Calabria, Italy — Francesco Calabrò
Vila Real, Portugal — Livia Madureira
Reggio Calabria, Italy — Francesco Carlo Morabito
Santiago de Compostela, Spain — María José Piñeira Mantiñán

Contents

Decision Support Systems for Urban Regeneration

A Participatory Approach as a Preliminary Action for Urban Projects Based on Nature-Based Solutions

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Abstract. Nature-based solutions (NBS) have been implemented in various cities and have been proven to provide climate change mitigation and adaptation, as well as other benefits such as increased biodiversity, improved air quality, disaster risk reduction, and better water management. To promote and implement these practices in urban design and planning, smart city research has emphasized participatory planning and approaches. This work investigates the benefits and drawbacks of participatory approaches to better include stakeholders in decision-making and create long-term change in urban areas. A case study in Turin was chosen to test a participatory facilitation tool for the rehabilitation of a public park. A workshop was organized to test a co-design gamification tool with university students. The aim was to redesign an existing park using nature-based solutions and incorporating users' opinions and suggestions. The goal was to increase citizens' sense of belonging and care towards the public space and to raise awareness about the importance of climate change mitigation solutions.

Keywords: Nature-based solutions NBS · Climate change adaptation · Participatory approaches · Gamification · Stakeholder involvement · Participatory planning · Co-creation · Co-design

1 Introduction

1.1 Problem Statement

Climate change is now unequivocally linked to human activities and its impacts, causing more frequent and intense extreme weather events that have damaged natural ecosystems and people beyond their ability to adapt [1]. Extreme climate-related events and biodiversity loss are among the five most pressing global risks, affecting countries and economies around the world to varying degrees [2]. Cities have a critical impact in this regard, and the increasing global population, estimated to be more than 70 per cent urban by 2050, will increase the relevance of anthropogenic impacts on global warming and

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greenhouse gas emissions [3]. Traditional urban planning methods have resulted in a system where land use, water management and permeability are compromised, and cities tend to be more vulnerable to extreme events such as heat waves, floods and rainfall variability. Land-use change resulting from extreme urbanisation has been identified as one of the main drivers of biodiversity loss [4]. In this context, the use of mainstream technical grey solutions, traditional engineering infrastructure, for water management and climate change mitigation is becoming more common but could instead be replaced by less damaging nature-based solutions (hereafter NBS) [5]. To be effective, NBS require a high level of involvement of stakeholders, practitioners and local urban actors, so the use of participatory approaches is often envisaged for better decision-making.

Objectives and motivations. The article focuses on co-design processes for urban green transformations, using facilitation strategies with gamification methods. In fact, this type of methodology is considered very interesting in terms of citizen engagement, because it uses the game to explain technical concepts in a simpler and more accessible way and is highly engaging. For the purpose, a case study in Turin was chosen, the regeneration of the Fioccardo Park, where a trial test was organised through a workshop with master students from the Polytechnic University of Turin, using a co-developed gamification tool. The case study site had previously been brought to the attention of the administration through a competition promoted by a private foundation. The aim was to allocate funds for the rehabilitation of urban and naturalistic park areas using NBS.

Paper structure. This paper is structured as follows: Sect. 2 describes the methodology used and the case study selected; Sect. 3 explains the results obtained from testing this methodology and the gamification tool for the case study; Sect. 4 draws conclusions and discusses the results of the process.

1.2 Literature Review on Participatory Approaches in NBS Planning

NBS have been described as an umbrella concept, that represents a series of different solutions, from different sectors of study and research, with a same goal: providing multiple human benefits and fostering climate change adaptation, and disaster risk reduction [6, 7]. NBS have been defined as "*Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience*" [7]. European local policies and initiatives have suggested the use of NBS by administrations in urban planning strategies. Design solutions like de-sealing, the use of porous pavings, bioswales, raingarden and rainwater run-off ponds for water treatment, if implemented on a planning scale, could pursue multiple goals at the same time, positively impacting sustainable urban water management and heat islands, as well as air quality, biodiversity increase, and life quality [8, 9]. For this reason, NBS have been recognized as a useful contribution to the fulfilment of the international commitments towards climate change. They are mentioned in the UN Sustainable Development Goals, SDGs, [10–12] and have been supported by international and European policies, such as the 2015 *Paris Agreement*, the 2015 *Sendai Framework for Disaster Risk Reduction* and the 2016 *New urban agenda*, the 2019 *European Green Deal*. Research on the topic has also been addressed by the European research and innovation strategy, through the *Horizon 2020/Horizon Europe* program, which counts a wide number of experimentations, like *Clever Cities*, *URBAN Greenup*, *UNaLab*, *Nature4Cities*, *CONNECTING NATURE*, *ProGIreg* and many more [2, 4, 13, 14]. The need to integrate nature in the planning strategies, which is at the base of the NBS approaches to urban and landscape planning, is now envisaged more than ever, often using GIS approaches, field surveys, and the selection of the most effective indicators [9, 15]. For nature-based solutions to be effective on climate change adaptation, the scale of application is crucial: it often requires landscape approaches, open collaborative governance and the involvement of different types of expertise, from technical, social and administrative sectors to local stakeholders and landowners. Participatory approaches can hence be critical to a project's delivery, since they allow stakeholder and citizen engagement from the preliminary stages of the project and are considered able to ensure the equitable delivery of multiple benefits, but also the public's acceptance and higher decision-making procedures [2, 5, 16]. Participatory approaches aim at empowering citizens, enabling users to participate in the design process, to generate ideas, discussion, and acceptance with generative toolkits and workshops. In literature, they have been divided into different categories by level of public engagement and by the one of power shared when important decisions are being made, thus describing different types of approaches [17]. The different types of participatory approaches can be defined along three dimensions, that form the so-called democracy cube of institutional design choices: first, looking at who participates and the length of the process, they can be divided into: auto selection processes, random sampling or targeted sampling; then, by drawing attention to the methods of communication, they can be defined as an articulation of interest, a negotiation, or an exchange of arguments and deliberations; or as a third option, they can be also divided by the capacity of the process to influence the administration and decision-making; For instance, if the only output is citizen's knowledge or influence on public opinion and society, it is defined as a low power participation strategy. If the output, on the contrary, goes towards a form of consultation by the citizens or co-decision cases, it is defined as a high power sharing approach [17–19].

At the European level, different initiatives have been developed under the Horizon program, including the reclaiming of derelict land for pocket parks, enhancing place identity among citizens, and increasing the recreational and aesthetic value of public green spaces. In this, stakeholder involvement is important and forms of dialogue and consultation are considered key to tackle potential conflicts, increase awareness and social acceptance for NBS, fostering pro-environmental behaviours among citizens [2, 20]. The literature suggests that NBS can advance social justice by explicitly engaging all stakeholders, contributing to sustainable and just transition, ensuring equal accessibility to public green spaces [21], but at the same time, they could exacerbate inequalities if not designed with sufficient caution [4]. Co-design and participatory planning processes can bring transparency in the governance processes, empowering citizens and civil society [21–23]. The *ProGIreg* Horizon project, for example, reports different levels of involvement, from one-way informational processes for the stakeholders and members of the public, to "*consult, involve, partner and empower*" modes, which shift control away from municipal authorities, who are most often the initiators of such projects, empowering stakeholders and community groups, throw the creation of *Living Labs* [24]. These approaches point out the importance of open and transparent planning processes and institutionalized forms of participation. The attention is pointed to how NBS may serve to challenge issues of inequity in urban planning and development processes, and whether alternative means of participation can overcome long-standing issues of exclusion [4, 24]. ProGIreg's lessons for replication processes are:

1. identify and get to know the target group, including their daily routines, to find anchor points for their engagement and design activities according to their needs.
2. involve stakeholders early in the process to develop a sense of ownership of the NBS and increase the likelihood of maintenance and care beyond the end of a pilot project.
3. communicate transparently and clearly, especially when working with disadvantaged groups, e.g. gain their trust by involving users and intermediary NGOs directly and from the outset.
4. identify and make visible the benefits of an NBS for the target group, noting that the more the NBS responds to their needs, the easier it will be to communicate and thus facilitate cooperation [25–27].

The use of gamification tools could facilitate the engagement of a wider number of citizens, considering their ambition of explaining scientific concepts in an accessible way, making people play with them, as demonstrated also by the B3 game in Hamburg and by the euPOLIS approach in Greece [28–31]. This new modality of engagement could help to overcome one of the barriers often referred to in the literature as "engagement fatigue", the repeated engagement of the same people. It could help facilitators and administrators to widen the active circle of already engaged people and give a voice to unheard citizens who do not vote, such as children and foreigners. The board game Start Park, tested in the case study, was chosen for this reason and is used to familiarise citizens with concepts such as climate change adaptation, sustainable planning and NBS.

2 Materials and Methods

2.1 Methodology

The methodology was elaborated after the literature review including a comparison of different participatory processes and case studies. It was applied for the case study of the regeneration of the Fioccardo park in Turin (Fig. 1).

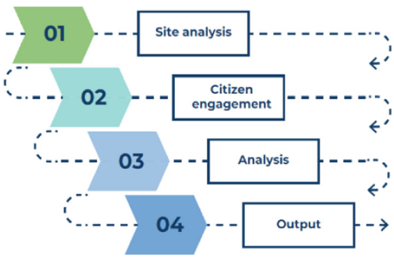

Fig. 1. Methodology

01 Site analysis. The first step was the site analysis, which included different actions: a review of the climate effects and policies for the city of Turin, a preliminary urban planning and legislative analysis. After that, an online data analysis of the population and site specifics and then an actual in situ site view and photographic report. **02 Citizen engagement.** The citizen engagement part was organized with a participatory workshop, held at the Polytechnic University of Turin, with the master students, that were asked to play with the selected participatory tool, Start Park, crafted to facilitate park co-design with the use of green and blue infrastructures, GBI. **03 Analysis.** At this step, the workshop's ideas and suggestions are analysed in a report, comparing the group's works singularly and then bringing them together. At the end of this step, to summarize the main overall considerations, a comparison table analysis is drawn. **04 Outputs.** Starting from the analysis' ideas, a preliminary project idea of the park is designed with the use of nature-based solutions, new furniture, and with the activities chosen. All the design choices were made based on the workshop output and elaborated by logical evidence.

2.2 Case Study

The site is located in the city of Turin, in the northern part of Italy, the capital of the Piedmont region (Fig. 2). The location is set inside an existing green area, in the southern part of the city, along the river Po. It is accessible by both private and public transport. The site was selected for the case study because it was considered an area of interest by the Turin Municipality and was a candidate for a renewal process by the local district 8. It is in an unfavourable situation due to lack of maintenance. On the other hand, it has a strategic location, close to several schools and sports centres and connected to other city parks.

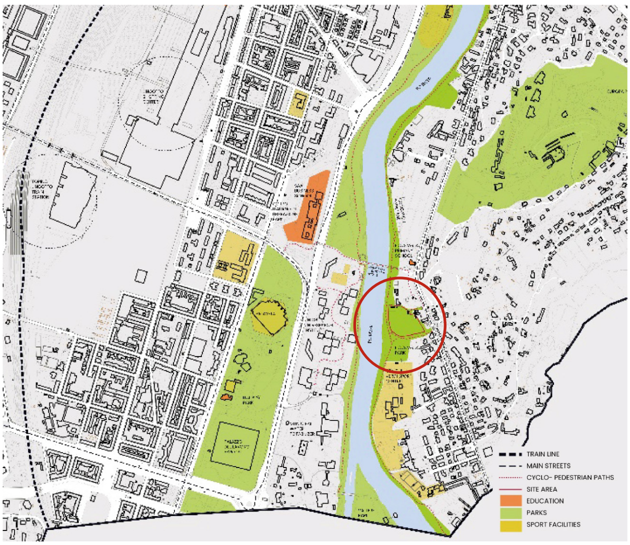

Fig. 2. Case study location Fioccardo Park

3 Results and Discussion

3.1 Site Analysis

City Climate Policies. To tackle climate change, the city of Turin has developed the following policy strategies: the *Piano strategico dell'infrastruttura verde* (Strategic plan for the green infrastructure), Progetto *Disaster Risk Reduction Insurance*, the *Valdocco vivibile* (Livable Valdocco project), that focuses on one neighbourhood of the city. Finally, the *Piano per la resilienza climatica* (*Climate resilience city plan)*, which is considered one of the most important tools for the city to direct sustainable actions towards city planning. The impacts of climate change that are expected in the coming decades in the urban area are mainly related to two problems: firstly, a rise in the average temperatures, which will cause an increase of the urban heat island effect and on the frequency of heat waves, droughts and heavy rainfall; secondly, a reduction of the average annual rainfall and river flows, resulting in a possible decline in agricultural productivity and in a loss of natural ecosystems [32]. The city has already experienced extreme events, in 1994, 2000 and 2016 with extensive damage due to flooding and from 2003 on with strong heat waves. This will increase the possibility of landslides, impacting mostly the hilly and the riverside areas with strong hydrogeological issues [33].

Torino's legislative and urban planning framework. The analysed plans are the following: the regional territorial plan (*Piano Territoriale Regionale* P.T.R.), the regional landscape plan (*Piano Paesaggistico Regionale* P.P.R.) of the Piedmont Region and the general town plan (*Piano Regolatore Generale* P.R.G.) of the municipality of Turin. The Fioccardo park area is designated by the municipality for use as a public urban park. The area is classified as having a high probability of flooding according to the flood directive (*Direttiva alluvioni*) due to its location within the river buffer zone. Therefore, any interventions that may harm the watercourse or natural ecosystem are restricted. The promotion of slow mobility is encouraged.

Site specifics. The site was initially analysed using aerial pictures, street views, and technical regional cartography CTR. Subsequently, an in-situ inspection was conducted. The site is connected to other city parks via a pedestrian path that runs from North to South. The accesses and riverside street were restored in the 1980s to provide the Fioccardo district with access to the river after years of privatization. The site's main driveway remains a private road, on which the municipality has established a right of passage. The pathways are poorly maintained, with gravel paving and garbage on the ground, as well as holes that make for an unappealing view. Additionally, there is an illegal landfill in the area that should be reclaimed by the municipality.

Population. The population of Turin is ageing. Families in the area tend to be small, consisting of couples, single parents with one child, or singles, with a size ranging from 1 to 3 people. The Fioccardo neighbourhood has a high concentration of foreign families who have moved to Turin since the 1950s, with a steady increase in numbers up to 2011. The main groups of residents are from Romania, Morocco, China, and Peru.

3.2 Citizen Engagement

The citizen engagement was simulated with the use of the Start Park tool, during a participatory workshop held with the master students at the Polytechnic university of

Turin. The Start Park tool was developed under a Horizon 2020 grant and represents a citizen-led gamification process with the aim of re-designing underdeveloped urban green areas by leveraging on design thinking methodologies [34–36]. The choice came to this approach because it was a participatory tool specifically made for NBS application purposes and because it offers, unlike other approaches used in Horizon 2020 projects, like RESINS and GREEN SURGE, a high level of participation in the citizens. The serious game follows a similar model to the *Planning for real* one [19], using a gameboard with the site plan as a model for the collaborative design of the park. The gamification tool guarantees a co-designed park plan, that can be the starting point for a technical project once it is entrusted to a design studio. The citizen, divided into small groups, can share their ideas and discuss on the main problems of the requalification area and choose the solution they prefer. This way the tool opens the discussion by allowing citizen consultation and co-decision, as well as negotiation strategies between the small groups. In the first stages of the process there is also a dedicated moment for information sharing, where the technicians explain what nature-based solutions are and how they can be used, also having an educational value and promoting sustainable good practices. It has a very intuitive mechanism, being organized as a traditional board game, with a board, activity cards, and roles to play [32–34]. For engagement simulation, it was asked the students to play the roles of the selected stakeholders involved in the process of the park regeneration (Fig. 3).

Fig. 3. Scheme of the Start Park tool gamification process, the three rounds.

The workshop was articulated in groups, to have multiple tests and confront the results. The engagement process, that in a real participatory process would have been planned in different moments, was organized in one morning of activities. The first part involved a theoretical lecture on the participatory processes and an introduction on the concept of nature-based solutions and the rules of the game, with the aim of informing the different stakeholders of the objectives of the participatory process. This section plays an important role because, as demonstrated by the *Unalab* project, the citizens have only a vague or no understanding of what participation means [24]. The introductory moment also allows the participants to know each other, collaborate, and build trust. The second part involved a presentation of the case study analysis. The third part was left to the serious gaming activities, divided into rounds with a fixed time schedule (Fig. 3). The students were divided and assigned to three groups and had 15 min to familiarize with the board and the cards, asking questions. They were also encouraged to act and defend their choices in the simulation playing the role of the assigned stakeholder.

In the first round, they had to address the problems of the area by choosing which nature-based solutions to use with the *GBI cards* (Green and Blue Infrastructure cards). This kind of cards present different solutions to collect, store and move first flush rainwater, also giving a rough evaluation of the construction and maintenance costs and its effects on climate change mitigation and adaptation. They could use a maximum of 2 *Punctual GBI* cards for collection and rainwater storage, 1 *Linear GBI card* to move the water, and 1 *Surface GBI card*, for extensive solutions. Depending on a defined budget, they were asked to select a set of cards to create a uniform system able to manage rainwater during extreme events. The participants were also asked to give design suggestions of the solutions, placing the solutions on the board. They were encouraged to justify their choices with sketches or notes on the game board to stimulate the debate and agreement on the final choices. In the second round the students had 30 min to choose their park's preferred furniture by using a maximum of 3 *Furniture cards*. For the third round, they had to decide which kind of activities, like concerts, treasure hunts or sport games, they would like to organize in the park after the renovation, with maximum 3 *Activity cards*. This part tries to focus also on use and maintenance of the park, leveraging on the community engagement activities. At the end of the process, it was given an extra 15 min to organize the presentation of the results, summarizing the major negotiations and key solutions chosen on the class's blackboard (Fig. 4).

3.3 Analysis

The output was analysed using a comparison table (Fig. 5), which served as the basis for the final project by collecting and utilizing all the common ideas from the groups. Despite the similar topics that all working groups focused on, such as the need for filtering systems, they chose different solutions to address it, including filter drains, wet canals, or tree-lined filtering boxes. The identified need for pavement solutions for the parking area is a common point. This will make the area easily accessible by car, facilitating the envisioned activities and improving accessibility for people with mobility impairments. The design strategies for resilience to climate change are evaluated using a point-based system in the GBIs cards (refer to Table 1). Additionally, each card is assigned a rating from 1 to 3 for construction and maintenance costs. This way each group could understand by playing at the game, the project's efficacy in climate change adaptation towards the contrast of droughts, flooding, and heat waves risk, but also the effort for the improvement of water quality and biodiversity support. The scoring criterion for the cards was developed by the technical side of the developer‘s group,

Fig. 4. Students engaging in the workshop's participative part and presenting the results.

Iridra spa, where a team of experts rated the different nature-based solutions proposed for the game based on their professional experience as chemists, biologists, environmental engineers and architects. For the educational purpose, some cards referring to traditional grey infrastructures were also inserted, to show the difference in term of environmental impact with the NBS ones. All the groups opted for small cost management, from 10 to 13 points, obtaining different results in terms of Climate Change adaptation, from 31 to 38 points. Another idea expressed by the participants is the need to create a gathering area for the community, where events could be organized, like a picnic area or a platform area. It was pointed out the need for shadowed seating areas, with attention to the elderly ones needs and the urban heat island effect. Attention was paid to the younger children with educational activities, like the creation of a school or community urban gardens or treasure hunts and sports matches, with a collaboration with the nearby sportive centre. The game had a good participatory level and positive student's feedback. The solutions developed by the three groups were different one from the other, even with the same starting point, giving evidence of the variability of the process, that was analysed and summarized in Fig. 5.

3.4 Output

The project originated from the analysis of citizen consultations, incorporating suggestions and needs from workshops into a preliminary plan. For the water management aspect of the park, all groups agreed on the use of nature-based solutions, proposing a

GROUP 1

6 STAKEHOLDERS

1. A Sporty woman
2. A dog owner
3. A young worker
4. A specialized architect
5. The Fioccardo elementary school director
6. An old woman.

GBI SOLUTIONS

- *2 punctual solutions:* Naturalistic pond and Raingarden
- *1 linear solution:* Filter drains
- *1 surface solution:* Green plastic gratings

FURNITURE

- A Gazebo/pergola
- A sport and well being path
- An entertainment area

ACTIVITIES

- Treasure hunt
- Community Goals

PARTICIPATORY METHODOLOGIES USED

- Discussion of advantages and disadvantages of each solution
- Negotiation between the group members

GROUP 2

7 STAKEHOLDERS

1. The Municipality's employee
2. The schoolteacher
3. A landscape architect
4. A mother living in the neighbourhood
5. A student
6. A runner
7. An old man.

GBI SOLUTIONS

- *2 punctual solutions:* Naturalistic pond and Phytodepuration for gray water treatment
- *1 linear solution:* Filter drains
- *1 surface solution:* Green concrete gratings

FURNITURE

- Water games and fountains
- Seating
- An entertainment area

ACTIVITIES

- Educational activities
- Community Goals

PARTICIPATORY METHODOLOGIES USED

- Solution comparison over efficacy and maintenance costs
- Organized discussion: participants talking in turns

GROUP 3

8 STAKEHOLDERS

1. The municipality's employee
2. A schoolteacher
3. A landscape architect
4. A father
5. A student
6. A dog owner
7. A sporty man
8. An old woman

GBI SOLUTIONS

- *2 punctual solutions:* Naturalistic pond and Tree-lined Filtering boxes
- *1 linear solution:* Wet canals
- *1 surface solution:* Green plastic gratings

FURNITURE

- Street lighting system
- Seating
- Picnic area

ACTIVITIES

- Treasure hunt
- Community Goals

PARTICIPATORY METHODOLOGIES USED

- Organized discussion: participants talking in turn
- Voting-based approach to the decision making: each participant had to vote 3 cards in turn, explaining their reasons

SOLUTIONS IN COMMON BETWEEN 3 GROUPS

- Naturalistic pond
- Community Goals

SOLUTIONS IN COMMON BETWEEN 2/3 GROUPS

- Filter drains
- Green plastic gratings
- Seating
- Entertainment area
- Treasure Hunt

THINGS ALL GROUPS GENERALLY CONCORDED ABOUT

- The need of filtering systems to help water management
- The need for pavement solutions for the parking area
- An event area for the community events
- A shadowed seating area to rest, work or have picnics
- The need to gather the community: with games, educational or sportive activities

Fig. 5. Comparison table analysis of the group's Participatory Approach workshop.

Table 1. GBIs cost resilience comparison table.

Point system		Group 1	Group 2	Group 3
Costs	Construction	6	6	7
	Maintenance	4	4	6
	Drought	6	5	5
Resilience to climate change risks	Flooding	7	5	7
	Heat waves	8	7	10
	Improvement of water quality	9	9	8
	Biodiversity support	6	5	8
Final results		10 Costs points/36 Climate change points	10 Costs points/31 Climate change points	13 Costs points/38 Climate change points

naturalistic pond and filter drains. The pond was situated in the centre of the site, below a natural slope, to facilitate natural water collection. In addition, the site's design was equipped with five filter drains to collect and channel water from all areas to the pond. Furthermore, a linear rain garden strip was included along the asphalt road, as suggested by Group 1, to divert water to the sides in the event of extreme rainfall, solving the problem without the need for a pipe system. The new parking area at the end of the road will be constructed using permeable green plastic pavements. All groups agreed on the need for an event area to organize community events and bring people together. This could include games such as treasure hunts and educational activities for children, as well as creative recycling activities, time banking, and other community goals. In response to this request, it was designed an open-air arena, with three terraced steps, to realize with a drystone wall and soil, with a natural-looking and permeable structure, to reduce the structure impact to the minimum. It was also mentioned the use of music or theatre events to raise the necessary funds for the maintenance of the new structures, with the support of the local associations, like the local neighbourhood activity house (*Casa del quartiere*) and the use of the so-called *collaboration pact* (*patti di collaborazione*) to establish between the citizens and the municipality. All the paths of the park are going to be refurbished with clay and calcestre paving to have a new look and an easily management. The white calcestre was chosen for its albedo contrasting properties and high infiltration rate. Around the arena are going to be placed more tall sized trees, to create a shadowed area along the riverside. In the south part of the park, it is going to be created a picnic area, with benches and tables, where to organize community lunches, open-air smart working and cards or chess competitions for the elderly. In the nearby area the proposal is to grow a small urban garden, so that the local school and the citizens, could use it as a free time and learning activity, to teach the pupils the importance of biodiversity, food quality and spread sustainable good behaviours.

4 Conclusions

The gamification method facilitated a high level of engagement and shared decision-making power with citizens. The simulation allowed students to express their ideas and gain a comprehensive understanding of the design process. The tool provides administrators with a project ready for the implementation and realisation, with the help of facilitators. Participatory approaches require time and money to implement, but have been proven successful in recent cases where public works were halted due to citizen protests, demonstrating the necessity of citizen engagement in the process. Administrators and facilitators must pay attention to the expectations created during the engagement process and to the delivery schedule. The tool's advantage is the establishment of clear monetary and planning constraints and its communication to the citizens. Another benefit comes from re-establishing direct contact between citizens and government, which builds trust between stakeholders and better responds to citizens' needs. Further investigation could go into overcoming the bureaucratic and timing obstacles for the use of participatory approaches and the possibility of developing active agreements between citizens and administrations, such as citizenship pacts. Additionally, conducting environmental and social impact assessments of projects is crucial to aid in the decision-making process. Europe's concept of Nature-Based Solutions (NBS) promotes participation and social return, making these projects highly compelling. With over 200 active NBS projects at the European and global level, there is ample opportunity for improvement through the integration of technology, such as a digital app or website, to enhance participatory approaches. The objective of this work was to investigate the integration of participatory approaches and Nature Based Solutions. One specific gamification tool was analysed in detail and practically tested it to engage stakeholders in the decision-making process. This research identified the key steps of a participatory design process. The methodology was tested successfully in the case study and is suitable for future applications in the renovation and regeneration of urban parks.

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ITACA Plus: A New Methodology to Support Urban Design

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Abstract. The imperative for sustainable development and building performance dates to the 1960s, but recent scientific literature emphasizes the need for a holistic perspective considering the intricate interplay of buildings, their surroundings, and the broader urban ecosystem. In this context, diverse methods and tools have emerged to assess and enhance cities' sustainability. This paper focuses on Neighborhood Sustainability Assessment Tools (NSATs) as comprehensive instruments, encompassing qualitative and quantitative dimensions and aligning with the modern sustainability paradigm. The objective is to propose a comprehensive NSAT integrating the ITACA one in order to measure different sustainability aspects. The research methodology involves analyzing eight prominent European NSATs, delving into scientific literature, studying ITACA's documents, and incorporating expert interviews and questionnaires to propose an innovative evaluation model. This paper concludes with an analysis of the strengths, limitations, and potential future developments of the proposed model.

In summary, this paper provides a thorough exploration of urban sustainability assessment contributing to advance the understanding of urban sustainability and offering insights for future developments in this critical field.

Keywords: ITACA · Sustainable Development · Assessment Tools · NSAT

1 Introduction

The concentration of the world population in urban areas is currently 54% and forecasts say that by 2050 two thirds of the world population will live in cities [1]. This progressive urbanization underlines the urgency of sustainable development [2, 3] making cities emerge as focal points where the pursuit of sustainability becomes both challenging and crucial [4, 5].

Among the strategies implemented to promote the sustainable development are the United Nations' Sustainable Development Goals (SDGs), developed in 2015 [6] which are currently a powerful reference in terms of sustainability and help guide choices toward a complex sustainability paradigm based on five pillars: environment, economy, society, innovation and governance [7].

Despite growing awareness, challenges still exist in operationalizing the SDGs and the sustainability paradigm at the local level including difficulties in prioritizing SDGs,

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the lack of financial resources, the lack of available data and non-mandatory guidelines [8–10].

In addition, a range of methods and tools are accessible for evaluating and shaping urban sustainability, which, while not explicitly rooted in the SDGs, offer the potential for complementary approaches. These are the Neighbourhood Sustainability Assessment Tools (NSATs) [11–13] which are multicriteria tools created to measure the environmental sustainability of buildings and are rapidly evolving to consider numerous aspects of sustainability and broad spatial scales [5, 14].

The present paper fits in this context with a double purpose:

1. to investigate whether and how the NSATs could help to design and measure urban sustainability projects considering the objectives proposed by the SDG11 "Make cities and human settlements inclusive, safe, resilient and sustainable" [6, 15];
2. to propose an implemented NSATs able to properly represent the five-pillar of sustainability starting from one of the main NSATs in Italy.

After this introduction, the paper is organized as follows: Sect. 2 provides the research methodology used in the study. Section 3 presents the implemented NSAT. Section 4 concludes the paper by clarifying the main findings and the innovation of the work carried out.

2 Research Method

This research moves from the Italian NSAT called ITACA Urban Scale (ITACA-US) [16] developed by the "Institute for Innovation and transparency of procurement and environmental compatibility" (ITACA), an agency of federal type for impulse of the Italian Regions.

The decision to base the research on ITACA is mainly attributable to 3 factors:

1. differently from other NSATs, the ITACA-US has strong connections with the Italian regulatory framework to consider sudden changes in the national and regional regulatory environment
2. the ITACA-US presents an open structure that allows various aspects of sustainability to be explored, deepened and integrated;
3. the ITACA-US assessment framework is easy to understand although mathematically robust and allows for the proposal of modifications and additions. It is based on a hierarchical structure composed by 11 areas, 10 categories and 65 criteria: the areas identify the macro aspects of sustainability; the categories deal with specific aspects of the areas; the criteria represent the evaluation items of the NSAT. Every criterion is linked to specific measurable quantities, referred to as indicators, which allow for the quantification of the urban area's performance concerning the considered criterion [14].

The overall assessment of performance according to the ITACA-US takes place by assigning scores to the criteria through the normalisation of the indicators attributed. These are then weighted according to the weight of the criteria and aggregated to obtain scores for categories and areas. Finally, the area scores, given their weights, generate the Final Score, representing the overall energy-environmental sustainability of the neighbourhood.

This structure is similar to that adopted by the main NSATs and therefore makes comparison and integration easier [10].

Starting from the current ITACA-US, the following research method has been applied to propose an implemented version of this tool (Fig. 1).

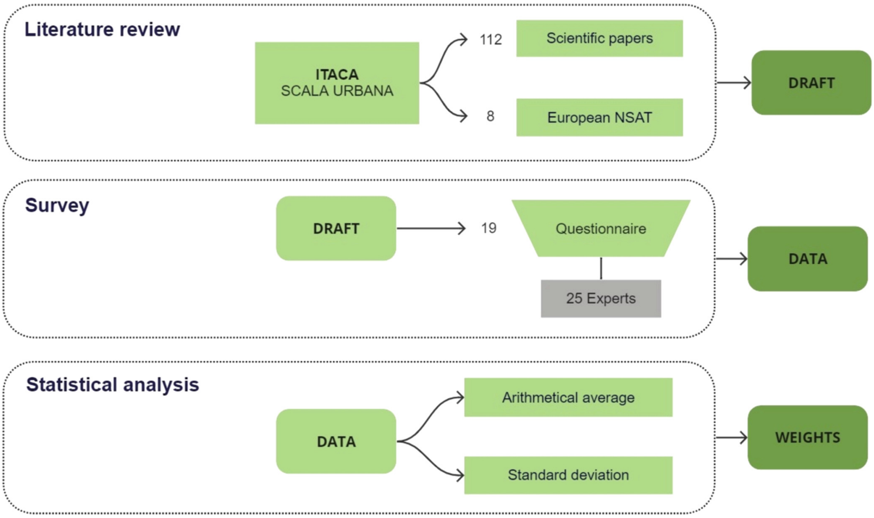

Fig. 1. The research method

2.1 Literature Review

The first phase deals with issues of content. The purpose of this step is to create a new assessment model that contemplates the latest sustainable development paradigm and equally considers the components of sustainability. This phase consists of an analysis of scientific papers including 112 publications written from 2010 to 2023 and 8 of the most used NSATs in Europe[1]. The bibliographic search was carried out through the Google Scholar database and Scopus, using the search strings: "SUSTAINABILITY,

[1] The 8 NSATs investigated are: Leadership in Energy and Environmental Design (LEED) v4.1 for Cities and Communities, Building Research Establishment Environmental Assessment Methodology (BREEAM) Communities, Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) for Urban District, Haute Qualité Environnementale (HQE) SUSTAINABLE URBAN PLANNING, Haute Qualité Environnementale (HQE) PERFORMANCE QUARTIER, ECO-QUARTIER en faveur des villes et territoires durables, Green Building Council (GBC) DISTRICTS and Liderar pelo ambiente na procura da sustentabilidade na construção (LIDERA) V 2.00.

ESG" or "ITACA" or "NSAT" or "SAT" or "CITY SUSTAINABILITY, SDGs" or finally "EUROPEAN SUSTAINABILITY PROTOCOLS".

The analysis of the scientific papers reveals a predominant focus on infrastructure, mobility, and resource management, often neglecting social aspects [17]. Topics commonly addressed include site, energy, water, materials, infrastructure, transport, and spatial planning while cultural, business, innovation, financial, and economic factors still receive limited attention, although innovation is recognized as crucial for adaptability [18]. Lastly, socio-economic criteria (i.e. affordable housing and inclusive communities) are still insufficiently integrated [19–24].

The analysis of the 8 NSATs revealed that these are dominated by environmental criteria and consequently undervalue the social and economic considerations of sustainability, finally the human factor of sustainability is generally underrepresented. For example, the three most important factors for citizens' perceptions of liveability have been identified as: safety, affordability and sense of community, but the NSATs analysed poorly address the social aspects [17]. In fact, the most virtuous seems to be the GBC, which awards up to 43 points over 100 to the "Neighbourhood Organisation and Planning" category. In second place we find BREEAM with a dedicated subcategory, while the LEED and DGNB investigate social aspects by relating them to thermal, acoustic and visual comfort.

The outcome of this phase is a preliminary draft of the implemented ITACA-US structured in 10 areas, 25 categories and 54 criteria. The newly implemented NSAT, called ITACA Urban Scale Plus (ITACA-USP) from now, is composed by: 10 areas, 10 categories and 44 criteria from ITACA-US; 2 categories and 3 criteria from BREEAM; 2 categories and 2 criteria from LEED; 2 categories and 3 criteria from GBC; 2 categories and 2 criteria from DGNB; 2 categories from HQE; 2 categories from ECOQUARTIER; 3 categories of LIDERA.

In particular, 23 criteria from ITACA-US were abandoned because they were not present in the European NSATs analysed. This choice was made to ensure consistency and alignment with international standards. Indeed, the comparability of the performance of urban transformations in Europe, evaluated with different NSATs, is a crucial element because in a context in which European cities face common challenges, it is essential to have uniform and shared assessment methods. The harmonisation of international NSATs and the definition of common indicators would allow a more accurate and objective assessment of urban transformations, facilitating comparison and mutual learning between cities. For this reason, eliminating non-shared criteria allows us to focus on those that are considered indispensable at the European level.

7 ITACA-US criteria were grouped or modified because it was observed that if considered individually, they would have dispersed and complicated the search. Combining these criteria makes it possible to deal more effectively and coherently with the subject in question, reducing ambiguity and improving understanding.

In addition, 5 criteria were added because indicators were missing to assess the two new pillars introduced, governance and technical aspects. This was a crucial step to ensure that the new NSAT fully and accurately covered all relevant areas. Adding new criteria made it possible to assess more precisely the effectiveness and impact of the new aspects introduced. Likewise, 5 more criteria were added due to their innovative nature. These new elements allow for a more complete and up-to-date perspective.

At the end of this phase, a list of areas, categories, criteria and indicators was obtained. In order to provide an assessment tool, it turned out to be necessary to identify and integrate the weights.

2.2 Survey

The second phase deals with the evaluation problems of the newly developed evaluation model. After modifying areas, categories and indicators (Sect. 2.1), the question arises as to what weight these elements have in the pursuit of sustainable development objectives.

In order to obtain definitive weights for the new ITACA-USP, we consulted experts through a questionnaire whose objective was to reason about the importance of the constituent elements of the ITACA-USP.

The questionnaire was administered to a sample of 25 experts with different backgrounds using an online mode based on MS Form [25]. To reach a large number of respondents, the questionnaire was submitted partly online and partly in-person with an overall response rate of 80%.

The expert sample consisted of:

- 64% Academic professors
- 16% Researchers
- 12% Technicians
- 8% Freelancers in architectural and urban fields.

In total, the questionnaire comprised 145 questions: 42 are open-ended questions, 70 multiple-choice questions and 32 questions using the Likert scale [26].

At the end of this second phase of the research method we have an ITACA-USP integrated with weight range for each area, category and criterion. For example, emerged that the "Housing" category weights can vary from 15% to 43%. It was then necessary to proceed a statistical analysis in order to define definitive weights.

2.3 Statistical Analysis

The last phase of this research included the aggregation of data collected by questionnaire. The statistical elements used in this phase have been the arithmetic mean, the standard deviation and the normalization.

The arithmetic mean has been applied to standardize the experts' answers to the questionnaire. The method of analysis by arithmetic mean is preferred in cases of strongly skewed distributions [27]. In fact, it was felt that the experts asked to answer the questionnaire could unintentionally favor their area of expertise.

The standard deviation aimed at clarified how far the values deviate from the sample mean.

With the calculation of the standard deviation, it was analyzed how far the value found with the mean reflected the true trend of the stated preferences. In fact, the lower the value of the standard deviation, the more the values are concentrated around the mean value and vice versa, the higher the mean value, the more the values are dispersed.

The weights obtained from the questionnaires and averaged were then normalized to obtain a percentage distribution.

3 ITACA-USP

The research framework conducted to a new version of the ITACA-USP, the contents of which are summarised in the following table (Table 1):

A significant innovation of the ITACA-USP concerns the introduction of sustainability pillars into the weighting system. They were introduced to balance the mutual importance in the quest for neighbourhood sustainability. These values were then subdivided to assign a thoughtful weight to each area included in the sustainability pillar assessed. This choice was made considering the weighting system of DGNB tool, which has received a broad positive assessment in the scientific literature [6, 26].

For this reason, when 2 areas refer to the same pillar, these are weighted 10% each, whereas if only one area refers to a pillar, this area takes 20% weight.

Instead, the category "Housing" is the one with highest priority (8%), although it is followed by one percentage point by the categories "Administration, Urban Landscape, Energy and Heat waves" (7%). It is not surprising that the highest weights were given to environmental aspects and the topics that are part of a very strong and long-standing debate (Table 1).

On the contrary, some categories (as "Health, Safety and Employment") received low weight probably due to their novelty as topics of urban interest and their recent introduction in the NSATs.

Regarding the criteria, it is not surprising that the highest weights were attributed to aspects concerning the environment and to two issues that are part of a very strong and long-standing debate: energy supply ("Local production of renewable energy" 3.9%) and atmospheric emissions ("GHG emission intensity" 4.9%).

In contrast, the criteria considered as least important turned out to be "Responsible Infrastructure Supply" (0.6%), "Social Site Management" (0.5%) and "Parking areas" with the lowest weight of 0.4 percentage points. The reason for these results is probably due to a different perception of these criteria than others. For example, even though the literature stresses their importance, parking areas are perceived in Italy as an issue to be solved by the PA and not yet an element of sustainability.

Furthermore, the ITACA-USP introduces reward points, allowing for localized adaptation to specific geographical contexts, considering unique characteristics and urban area needs. ITACA-US does not currently include this dynamic, but it was decided to introduce it since it is a common and effective dynamic in international NSATs.

Table 1. ITACA-USP summary

PILLAR	AREA	CATEGORY	CRITERION	W
Governance (20%)	Governance (10%)	Administration (7%)	1.01 - Participation (ex-ante)	1,5%
			1.02 - Social management of the worksite	0,5%
			1.03 - Participation (in itinere, ex-post)	1,0%
		Innovation (2%)	1.04 - Green building policy and incentives	1,7%
	Architecture (10%)	Approach (4%)	3.01 - Project preparation methods	0.8%
			3.02 - Design Team Qualification	2.3%
		Process (2%)	3.03 - Management Criteria	1.2%
			3.04 - Life Cycle Assessment	2.7%
Technical (20%)	Urban (10%)	Soil use (4%)	2.01 - Adjacency to the Consolidated City	2,1%
			2.02 - Soil Conservation	3,0%
			2.03 - Conservation of the Built Environment	0,9%
			2.04 - Redevelopment of brownfield sites and contaminated land	1,3%
		Urban landscape (7%)	2.05 - Relationship with the context	3.8%
			2.06 - Social role of public space	1.5%
			2.07 - Dedicated parking areas	0.4%
	Mobility (10%)	Public transport (5%)	8.01 - Scale of the road network	1.6%

(*continued*)

Table 1. (*continued*)

PILLAR	AREA	CATEGORY	CRITERION	W
			8.02 - Accessibility to public transport	2.2%
			8.03 - Availability of safe (protected) bicycle routes	1.9%
			8.04 - Accessibility of pedestrian routes	2,8%
			8.05 - Accessibility to shared mobility	1.5%
		Road safety (4%)	8.06.1 - Road safety - ex-ante - ex-post monitoring	2,3%
			8.06.2 - Road safety - design	1.2%
Social (20%)	Public spaces (10%)	Health (1%)	4.01 - Relevance of public open space	2.5%
		Pedestrian safety (2%)	4.02 - Safety of pedestrian routes	1.2%
	Society and culture (10%)	Neighborhood (2%)	9.01 - Proximity to main services	1,6%
			9.02 - Proximity to leisure facilities	0,9%
		Diversification (6%)	9.03 - Mixing	2.3%
			9.04 - School complexes in the neighbourhood	0.7%
Environmental (20%)	Urban metabolism (7%)	Water (4%)	5.01 - Soil permeability	2.6%
			5.02 - Intensity of water treatment	2.2%
			5.03 - Wastewater management	2,2%
		Waste (2%)	5.04 - Accessibility to waste collection	2,1%
		Light (2%)	5.05 - Light pollution	0.8%

(*continued*)

Table 1. (*continued*)

PILLAR	AREA	CATEGORY	CRITERION	W
			5.06 - Solar orientation	1,3%
		Gas/aria (3%)	5.07 - GHG emission intensity	4.9%
		Sound (2%)	5.08 - Noise pollution	1.1%
		Materials (3%)	5.09 - Responsible infrastructure supply	0.6%
		Energy (7%)	5.10 - Local Renewable Energy Production	3.9%
			5.11 - Energy communities in urban areas	1,4%
			5.12 - Carbon dioxide emissions	1.9%
			5.13 - CO^2 sequestration	3.5%
	Biodiversity (6%)	Ecosystem (3%)	6.01 - Presence of areas capable of providing greater ecosystem services	2,1%
			6.02 - Design of green areas and choice of plant species	2.2%
	Adaptation (7%)	Drought (6%)	7.01 - Extraordinary water pipeline maintenance	3.6%
		Heat waves (7%)	7.02 - Increasing tree planting on streets, squares and parking areas	1,8%
			7.03 - Intensification of natural urban ventilation	1,9%
			7.04 - Heat island effect	3.5%

(*continued*)

Table 1. (*continued*)

PILLAR	AREA	CATEGORY	CRITERION	W
		Hydrogeological risk (5%)	7.05 - Reduction of building pressure	1.8%
			7.06 - Reducing the amount of rainwater entering the sewer system	1.1%
Economic (20%)	Economy (20%)	Housing (8%)	10.01 - Affordability of residential property	0,8%
			10.02 - Affordability to residential rental	1,0%
			10.03 - Composition and variety of housing supply	1,8%
			10.04 - Value stability	1,0%
		Employment (2%)	10.05 - Employment potential	1,8%
BONUS			Regional Priorities (max 5 points)	

4 Discussion and Conclusion

This research aims at enhancing the sustainability assessment panorama by introducing a first version of the ITACA-USP, an updated version of ITACA-US tailored for urban applications that incorporate the latest five-pillar definition of sustainability [7].

This research aims at contributing to the scientific progress in two main ways: i) It presents a possible solution to assess urban sustainability in Italy proposing a tool designed to accommodate the specificities of the Italian context and territories; ii) It contributes to advancing the research on NSATs initiated by ITACA and currently still halted.

The strength of the research lies in its comprehensive and holistic approach, offering an integrated view of urban sustainability. Similarly to the ITACA-US, the ITACA-USP is closely aligned with current legislation, utilizing a benchmarking system for performance comparison against national and international standards. This ensures that evaluations are in line with legislative directives, providing an updated reference framework.

The assessment process employed a thorough literature review, ensuring access to detailed and up-to-date information on the state of the art of NSAT. Additionally, statistical surveys were utilized to gather empirical and quantitative data, combining qualitative-quantitative methods to offer a comprehensive and nuanced understanding of the dynamics related to urban sustainability.

While the research offers a comprehensive approach, it still shows drawbacks. The extensive criteria demand significant time and resources, risking to limit accessibility and application. Moreover, a risk of potential criteria overlap emerges causing a risk of potential inaccuracies in the assessment. Additionally, a small and non-random sample size in the evaluation may limit representativeness and validity. Administering the questionnaire online may compromise accuracy and the compensatory evaluation approach may hinder identifying specific critical issues in urban interventions.

While ITACA-USP is still undergoing refinement, it marks the first tool to holistically study sustainability components within the circular methodology framework. Suggested modifications within ITACA-USP intend to rectify issues inherited from analysed NSATs and expand the questionnaire analysis to involve a broader group, aiming to resolve numerical and statistical uncertainties.

Looking ahead, the key areas for improvement are: i) overlapping criteria to be eliminated; ii) definition of benchmarks for each criterion; iii) consolidation of the model by application to case studies; iv) enhancing the automatic applicability of required data using BIM/GIS tools and new AI tools [28]; v) promoting large-scale initiatives for the application of NSAT not only in Italy but across European territories.

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An Overview of Tools and Methods for the Research Field of Urban Sustainable Development

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Abstract. Urbanization is one of the most significant developments of the 21st century. More than half of the world's population lives in cities, with estimates of up to 70 per cent by 2050. The Sustainable Development Goal 11, within the Agenda 2030, aims at making cities and human settlements inclusive, safe, long-lasting and sustainable. Achieving this objective passes through various factors, such as an adequate analysis of the territorial contexts, with their peculiarities, strengths and weaknesses; together with the use of proper decision support tools for modelling the complex interactions among the different elements of the territory and simulating impacts of different planning strategies, thus helping in the decision-making process.

In this regard, the following contribution aims to show an overview of the scientific literature produced to date, on a global scale, which focuses on achieving the objectives set for sustainable urban development, taking advantage of decision support systems.

In other words, we propose a review of scientific contributions which, thanks to the use of decision support applications, show how it is possible not only to measure sustainable planning interventions on an urban scale, but also to evaluate future scenarios and build efficient and effective policies and strategies in terms of governance and management of the territory.

Keywords: Sustainable Development · Urban Transformations · Decision-support tools

1 Introduction

Over the years, the topic of sustainable development has regarded more and more sectors and disciplines within its scope of intervention and has been discussed in various governmental and non-governmental forums. From "Our Common Future" published in 1987 by the World Commission on Environment and Development [1], it can be seen that sustainable development means that development is capable of ensuring "the satisfaction of the needs of the present generation without compromising the ability of future generations to achieve their own" [2].

Making our cities greener and more sustainable passes through the following cornerstones, from which to then develop the architecture of this contribution:

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- accessibility and usability on an urban scale;
- socio-economic equity;
- environmental impact;
- mitigation and adaptation to climate change.

These concepts, fully implemented in the development of regulations, strategies and urban policies [3], must, however, be validated in the planning process [4] through decision support applications that return the exact measurement, not only of the ex-framework ante, but above all ex-post, with the aim of building a citizen-friendly urban network. Interventions such as, for instance, the creation of green and blue infrastructures [5], the regeneration of degraded areas through soft/hard greening interventions [6], and risk management of environmental issues in terms of climate change [7], the opening of marginal and peripheral areas to the city [8], or the monitoring of small areas green to intercept problems of arboreal and/or environmental origin in the bud [9] managing to return a value that is plausible to the sector indicators, can and must be considered through applications such as GIS software, which is capable of providing an exact vision of the impact of such decisions in the short, medium and long term. The use of GIS as decision support has already proven efficient and effective in larger-scale areas other than urban and micro-urban ones. This tool, in fact, has long represented an essential support for risk analysis and real-time management of emergencies [10]. What we therefore want to demonstrate is the validity of the tool also on an urban and micro-urban scale [11], objectively and systematically reporting approaches and methodologies validated by the scientific literature. A specific focus was, then, made on safe and sustainable mobility frameworks in line with SDG11's targets within the Agenda 2030 [12].

The remainder of the paper is structured as follows: in Sect. 2, the conducted literature review and the related outcome are described; while, in Sect. 3, concluding remarks are presented.

2 Method and Results in the Data Set 'Urban Sustainable Development'

The methodology used has the aim of returning the main scientific articles published on the importance of using decision support applications in planning processes to achieve sustainable development on an urban and micro-urban scale.

To ensure a research outcome as objective as possible, we rely on the Bib-liometrix-R, a unique open-source tool, designed by Aria and Cuccurullo [13]. It represents an open-source device for quantitative research in scientometrics and bibliometrics and returns a structured analysis by intercepting several data, with the aim of deducing not only trends over time, but also of identifying changes in the boundaries of the disciplines, deriving the most prolific scholars and institutions for the chosen research topic and to show the "big picture" of the existing research of their firm. Divided into two research phases, in the first step, we examined the existing literature on the topic of Sustainable Urban Development, focusing the research through the insertion of some keywords within the WoS database, such as: "Sustainable", "Urban Transformations", "SDG11", "Green and Blue Infrastructure", "ArcGIS", "Geographical Information System", "Co-design", "Indicator". The choice of these keywords, which is anything but random, aims to provide a first, substantial screening of the literature produced which has sustainable development as its focus. However, it is worth noting that, in some contributions, the proposed indicators do not present a structured form and related measurability and repeatability features that an evaluation scheme would require. Once the first phase of filtering the literature through WoS was completed, in the second step the results were loaded into Bibliometrix to provide an exhaustive and objective picture of the topic. In particular, by applying sequentially 6 filters, we pass from 136.499 records to a subset of 490 noteworthy contributions (see Fig. 1).

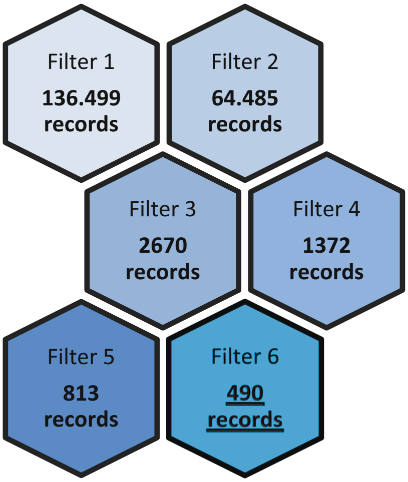

Fig. 1. Applied filters.

Specifically, filters regard information about research areas and topics but also publication years, language and document types. In particular, the selected language was English and we focused the research considering the productions published in the period between 2019 and 2023, to have a return of information that is as updated as possible and in step with technological innovations and scientific discoveries in the field of sustainable development. Moreover, both articles and proceedings papers have been included.

Some statistical analyses are thus provided on these selected contributions.

Figure 2 reports the annual scientific production which shows the trend of the articles related to the investigated research field. Thanks to the help of Bibliometrix-R, we tracked down the most relevant sources cited regarding the 490 articles in our study. Results show in the first positions, in decreasing order for the number of citations, the following journals: Accident Analysis & Prevention (623 citations), Energy and Buildings (524 citations), Building and Environment (461 citations) and Journal of Cleaner Production (364 citations). Therefore, it is clear that the majority of citations are related to environmental aspects, impact mitigation, adaptation to climate change and protection of citizens' health. This can be considered significant as it represents a measure of the sectoral relevance of the source.

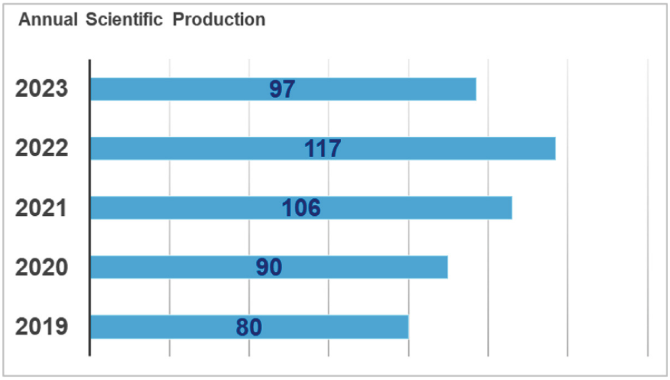

Fig. 2. Annual scientific production in terms of the number of published papers.

We considered it is necessary to present specific statistics regarding the countries in the world that have distinguished themselves for the production of scientific texts on the creation of decision support applications, for the planning of interventions, for sustainable development, actively involving the largest universities in the world in the topic and to the authors with the greatest production of articles on the topic. In detail, we report the top twenty for each. The map (see Fig. 3) shows the most influential countries, using a gradient of colors from lightest to darkest which underlines their greater or lesser importance in the global scenario for that country.

In this regard, China's position is not surprising, with 118 sector articles published and 956 total citations, as the Chinese government has for years launched the "Made in China 2070" plan which, among other things, puts into practice considerable funding and knowledge for the implementation of projects regarding sustainable development, ecological transition and the creation of environmental monitoring tools and equipment. The data make clear China's supremacy in terms of interest in the discipline; indeed, on the global scene, it is followed by the United States which, however, only has 41 published articles, highlighting the clear gap between them. A notable gap also manifests when comparing the Chinese giant with the most deserving European countries.

Figure 4 shows the most frequently used keywords. As can be seen, words such as performance, design, model and impact stand out, terms that are closely linked to those basic concepts, which are pivotal in the arrangement of planning work for urban sustainable development. Of equal importance, but in a secondary position in the cloud, we are not surprised to find terms such as indicators, public transport, built environment, and equity. As we expected, the cloud reiterates all the points touched upon by the literature of this review, as well as the "hot" topics in the sector on a global scale with a particular interest in the absolute models and impacts and, among others, at the risks and to all those components on an urban and micro-urban scale that characterize the good practice of sustainable urban planning.

Finally, we investigated the most cited scientific articles and enucleated, among the first ten of them, those which addressed the topic of mobility, transportation, and infrastructure within the context of sustainable urban development. In particular, even

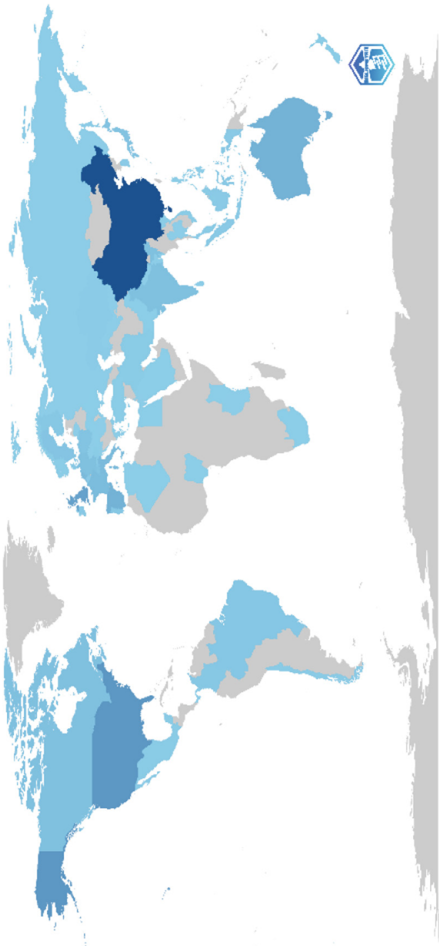

Fig. 3. Country scientific production.

Fig. 4. The wordcloud.

half of them are focused on this topic and related features, together with their link with SDG1's targets, are shown in Table 1.

As can be seen, all of them are perfectly in line with the targets defined within SDG11 which aims to make our cities safe and sustainable places by means of inclusive, fair and safe access to all urban facilities, among which a crucial role is played by mobility services. Accessibility and resilience of transport systems, therefore, become key factors to be analysed and properly maximised to pursue such a goal.

In particular Zhai et al. [14], determined the association between the severity of the pedestrian accident, weather conditions and other possible risk factors by means of a mixed logit model. It was found that both high temperatures and rain were associated with a greater probability of accidents resulting in deaths and serious injuries. For this reason, the study concluded that real-time traffic and weather data should be incorporated into dynamic message signs and in-vehicle warning systems, thus improving pedestrian safety in the long term. Also Borsos et al. [15] addressed the topic of the estimation of crash probabilities and severities with the aim of investigating how, in the event of an accident, motorists who are not on a collision course could behave as if they were. The study seeks answers on the feasibility of transferring information regarding surrogate collision and route crossing safety indicators. By exploiting data collected at an intersection and focusing on the interactions of left-turning and straight-moving vehicles, crash probabilities were estimated for different "near-crash" thresholds. By checking the correlation between them, the results demonstrated that the collision and path-crossing indicators are transferable. Crash probabilities calculated using the extreme value theory showed that one needs to be "harder" against course-crossing interactions, compared to collision-course interactions.

Further Fitzgerald et al. [16], investigated the feasibility of using bogie acceleration measurements of a passing train to detect the presence of bridge erosion. The approach is certainly innovative in the context of erosion detection and is advantageous as it works at normal train operating speeds. A bridge can be monitored under normal service conditions without the use of specialist monitoring vehicles. The study specifies that,

Table 1. Papers focused on transport systems within the ten most cited articles.

Article	Topic	Method	Link to SDG11	Number of citations
Zhai et al. [14] Diagnostic analysis of the effects of weather conditions on pedestrian crash severity	Pedestrian crash	Mixed logit random utility model	Safe cities for vulnerable users	102
Fitzgerald et al. [16] Drive-by scour monitoring of railway bridges using a wavelet-based approach	Infrastructure monitoring and detection	Train-track-bridge model and blind simulation tests	Safe transport systems	60
Da Mata Martins et al. [17] An indicator-based methodology for assessing resilience in urban mobility	Urban mobility resilience	Estimation of trip features through OD datasets	Resilient transport systems	33
Niedzielski and Kucharski [18] Impact of commuting, time budgets, and activity durations on modal disparity in accessibility to supermarkets	Modal disparity in the case of shopping trips	Commute-based and home-based accessibility models	Accessibility and equity	23
Borsos et al. [15] Are collision and crossing course surrogate safety indicators transferable? A probability-based approach using extreme value theory	Estimation of crash probabilities and severities	Extreme value theory	Safe transport systems	23

although no field tests were carried out, the excavation indicator performed quite well in both numerical models tested, which included added measurement errors and train-bridge interaction effects. Moreover Da Mata Martins et al. [17], proposed a resilience evaluation method that utilizes commonly available origin-destination (OD) datasets to assess an overall indicator of resilience. This approach takes into account the possibility of trips usually undertaken by motorized modes being shifted to active modes when the mobility system faces disruptions. In particular, the significance of resilient trips within the urban area has been examined by deriving the spatial dispersion of trips. Results indicated that distinct income degrees play a role in the responsiveness to alterations in resilience levels. Finally Niedzielski and Kucharski [18], examined accessibility to non-work activities. Focusing on accessibility to supermarkets, the research demonstrates how denser land use, accompanied by well-developed public transport networks, provides the basis for achieving modal parity. In particular, areas outside of high-density residential estates can benefit from public transport if they have good quality transport, providing more broad-based positive implications for mobility services and the environment.

3 Discussion and Conclusion

In conclusion, the paper provides an overview of tools and methods proposed in the scientific literature for supporting urban development planning strategies with a particular focus on transport systems and their role in the achievement of SDG11's goals.

In particular, by means of the Bibliometrix tool, some descriptive statistics have been provided and, then, a discussion focused on the most cited works is reported. As can be seen, most of them are aimed to make mobility services safe, especially for vulnerable users, and to enhance their levels of robustness against disruptions with advanced detection methods. Moreover, accessibility to non-work activities also gains attention. Indeed, generally, non-systematic trips are less considered because characterised by features which are more difficult to be modelled and foreseen; however, they play a crucial role for people during their leisure time.

The provided discussion, therefore, confirms the complexity of analysing strategies and interventions regarding urban sustainable development and the necessity of relying on suitable decision support tools which can return information not only on the current state but also in perspective on their applicability in terms of possible impacts and/or benefits in future scenarios. This represents a preliminary stage, starting by which more accurate analysis can be performed in order to provide scholars with useful insights on so a wide, and for this reason complex, topic.

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Heritage Communities Urban Living Lab (HeCo ULL): A Circular Methodological Approach for Co-Design Through Social Multi-Criteria Evaluation

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Abstract. This research aims to define an integrated methodological approach for activating and implementing Urban Living Labs focused on cultural resources, landscapes and assets, and their enhancement, shaped by the role of the local community and significant historical sites. The CHANGES project - Cultural Heritage Active Innovation for Next-Gen Sustainable Society - is the context to design a circular Urban Living Lab approach where evaluation acquires a central and enabling role. Social Multi-Criteria Evaluation (SMCE) is suitable for inclusion in this decision-making context, instigating a Collaborative Decision-Making Process within co-design phases that actively engage diverse stakeholders, incorporating preferences and facilitating consensus building. Specifically, SOCRATES represents an interesting multicriteria method to investigate for this purpose as part of a methodology that consists of multiple methods of work, design and research. The methodological proposal is the Heritage Communities Urban Living Labs (HeCo-ULLs) approach, a circular framework recognising multidimensional complex values and the aspiration to generate new, locally rooted, and community-driven values. The proposal incorporates the SOCRATES method across various Urban Living Lab development stages. This methodological approach has to be implemented and validated case-by-case, involving local actors and considering the peculiarities of different cultural heritages and related contexts.

Keywords: Urban Living Lab · Social Multi-Criteria Evaluation · Collaborative Decision-Making Process

1 Introduction

A cultural landscape represents a geographic expanse profoundly shaped by human culture and civilization, harmonizing natural and human-made elements across historical, ecological, social, and physical dimensions. These landscapes are visible repositories of

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societal growth and evolution across generations, as acknowledged by UNESCO (2019). This concept underscores the intricate interplay between human civilization and the environment, emphasizing the importance of preserving and celebrating both cultural and natural heritage for and with communities, whose relevance is widely recognised and highlighted by the "Convention on the Value of Cultural Heritage for Society", Faro Convention [1]. The Convention encourages and engages people to recognise the public interest in cultural heritage. It outlines the framework of citizens' rights and responsibilities in participating in heritage valorisation by defining them as "Heritage communities" [2]. More recently, the New European Bauhaus movement is based on the belief that cultural heritage and urban regeneration strategies are strongly connected at different scales: heritage can work as a "cultural capital" in shaping more beautiful, sustainable, and inclusive forms of living together, rebuild local identity and co-create sustainable and productive relationships among people and places [3].

In 2022, the CHANGES project (Cultural Heritage Active Innovation for Sustainable Society) started to explore the cultural heritage enhancement impact on society, with specific attention to archaeological sites. While numerous experiences have been acknowledged as successful instances, various criticisms have emerged [4]. Specific authors have highlighted that strategies for cultural and creative cities are frequently linked to urban branding, rendering central areas more appealing to tourists and a specialized creative workforce. Unfortunately, these interventions often trigger the phenomenon of gentrification, which poses a threat to the authenticity of many cities [5]. Culture should be a catalyst for building diverse and inclusive urban environments [6] by giving proper attention to the long-term social impacts of cultural strategies [7] and reimagining how communities can play a crucial role in city policies and the socio-economic transformation of resilient cultural landscapes and assets [8].

Different authors have underlined that cultural-led regeneration should be local, place-based, site-specific, and community-led [9] to reduce contemporary urban contexts' physical and social inequalities. The cultural texture of urban areas containing archaeological remnants forms a rich network of intricate values, encompassing economic and non-economic aspects. These values require recognition and practical application in local regeneration and development initiatives. These often interconnected but neglected cultural assets serve as a catalyst for engaging diverse stakeholders in valorization strategies that prioritise authentic experiences and cultural heritage enhancement [10]. This study incorporates the concepts of Living Labs, heritage preservation, collaborative decision-making processes [2], multifaceted value recognition, complex values and circular economy principles. A Living Lab is a user-centred innovation ecosystem that often operates in a spatial context, integrating research and innovative processes within a public-private-people partnership, including stakeholders and citizens as key actors [11]. It is founded on an inclusive philosophy, which aims to transform users into direct creators of value, contributing to the co-creation of new ideas, innovative scenarios, concepts, and related artefacts [12]. This is essential to facilitate more equal relational processes among the individual, local community, and organisational levels [13]. In particular, Urban Living Labs can play a key role in maintaining the relevance of cultural landscapes in rapidly changing urban environments. They bridge the gap between tradition and innovation, engage communities and contribute to the sustainability and vibrancy of our cities by preserving cultural heritage and its values [2]. This research aims to define a methodology to activate Heritage Communities in Urban Living Labs by elaborating a circular decision-making process able to integrate the knowledge of local resources and elaborate situated strategies based on community-driven and culture-led approaches and providing a toolbox for implementing a Collaborative Decision Support System (CDSS).

2 Urban Living Labs: Collaborative Decision-Making Process for Circular Design

2.1 Evolutions and Approaches of Living Labs

Living Labs (LLs) are open innovation ecosystems that operate in real-world settings. They employ iterative feedback mechanisms throughout the innovation lifecycle to generate sustainable impact. Penny Evans [14] of the Bristol Living Lab describes LLs as "places where citizens, artists, technologists, businesses and public sector organizations can come together to co-create ideas, tools, and technologies that address local challenges; a place for innovation and the exploration of new possibilities, where reflection and evaluation are integrated into the work process" [13]. Their main focus is co-creation, rapid prototyping and experimentation. The approach of LLs is specific to the world of open innovation and defines a user-centred ecosystem based on a systemic co-creation approach that integrates research and innovation processes in communities and real-life contexts where users are considered co-producers [15]. In November 2006, the European Network of LLs was founded under the Finnish Presidency of the Council of the European Union (EU). In the European interpretation of LLs, five main elements are combined [16]: active user involvement, a real-life environment, the participation of multiple stakeholders, a multi-method approach and co-creation. The European Network of Living Labs (ENoLL) has grown steadily over the years, parallel with the development of LLs approaches. Although there are common features between the various LLs, they can be implemented differently. Starting from structured methods for organizing user participation in innovation processes, multiple implementations of the LLs approach have occurred over time through the FormIT method [17], through the Belgian iLab.o [18], the Helsinki Living Lab and the Catalan Living Lab [19], up to the prototyping of the Territorial and Urban Living Lab [20].

Steen and van Bueren [21] describe Urban Living Labs (ULLs) as distinct from LLs because they have a clear territorial focus. They utilize various methods and modalities to encourage the social inclusion of residents and other stakeholders in experimenting with new ways of operating in their daily lives. Indeed, the Territorial Living Labs provide a coherent space for experimentation with the co-governance model of the Quadruple or Quintuple Helix [22]. This innovation model, implemented by the Amsterdam Pact in 2016, involves collective decision-making by at least five key actors: public and cognitive institutions, the private sector, civil society organizations or the third sector, and the unorganized public [23]. The latter refers to social innovators, creatives and other actors who wish to contribute and participate in local economic, cultural, and institutional development [24]. This alternative, open and multi-stakeholder governance model promotes a balancing of public, private, and community interests, which becomes essential for addressing new urban challenges. It requires consideration of a multitude of aspects simultaneously while operating in a field of complexity [25].

The ULL thus acts as a forum for innovation and dialogue in urban environments. It addresses real challenges by bringing together various stakeholders and interests for mutual learning and knowledge exchange. It is designed as a model of innovation for urban areas and aims to create active citizenship communities that promote co-creativity and serve as micro-centralities capable of innovating and supporting existing centralities or activating new ones [26]. In this perspective, ULLs provide an innovative environment to preserve and regenerate cultural heritage in urban areas by actively involving local communities in developing their neighbourhoods. This involvement increases the sense of belonging to the cultural resources, landscape, and assets, and promotes positive social and cultural impacts, generating new multidimensional values. This research proposes an innovative methodology for conducting Urban Living Labs in contexts where cultural landscapes have multidimensional wasted resources, and need to be considered from a circular perspective, with particular attention to evaluation processes.

2.2 Circular Design, Values Chain, and Urban Living Labs

The effective implementation of Urban Living Labs processes necessitates a deep understanding of diverse stakeholders' values, interests, and motivations. Navigating the complexity of these processes requires forging new connections and identifying partnership opportunities among people, institutions, industries, resources, and information. Cooperation and collaboration are essential to achieve meaningful scale and impacts in the sustainable and circular economy perspective. The Ellen MacArthur Foundation (2023) emphasizes the systematic integration of design to achieve circular economy goals. Their adaptive strategy, informed by the experiences of various design leaders, identifies six key design leverage points (Fig. 1) that, when combined, create an environment for circular transformation. Aligning with circular economy principles, the circular design encourages interventions upstream, addressing root causes. Collaborative action involves bringing together resources to respond systematically to circular design challenges. Successful collaborative action brings together qualities, expertise, innovation, capabilities, and community to answer a circular design challenge, engaging systematically across a dynamic and evolutive value chain, considering that working together in the creation process increases the possibilities of optimising the value for everyone (Fig. 1).

Approaching ULLs from a circular economy perspective involves redefining the role of designers, influencing design briefs, addressing skills gaps, offering the ideal decision space to practice enabling tools, communicating the value of circular products and services, and fostering mutual learning opportunities. A cross-disciplinary ULLs approach [25] brings together formal and informal leaders with circular design knowledge to build innovation capacity in a synergistic and symbiotic way. It shifts away from siloed design functions and embeds design upstream in collaborative decision-making processes. Implementing a ULLs approach necessitates exploring new rules at every process level to accelerate change and incorporate shared values. Organizations benefit from translating circular economy principles into language, approach, and aspirations. Different actors can collaborate to co-create organizational design principles, influencing

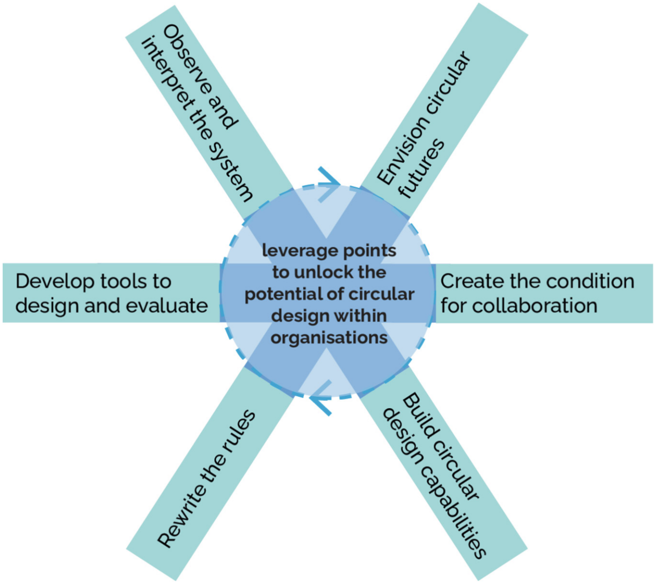

Fig. 1. Six design leverage points to unlock the potential of circular design within organisations (source: Ellen Macarthur Foundation, 2023, authors' elaboration)

governance, ownership models, and financing mechanisms for systemic change toward a circular economy regenerative by design.

3 Methodological Approach

3.1 Embedding a Social Multi-Criteria Evaluation in Urban Living Labs

ULLs' literature analysis shows that evaluation is not often addressed despite their process's focus on the recognition and co-production of multidimensional complex values. The MOVE21 research project [27] carried out an impact analysis framework for LLs, selecting three levels, which mark the methodological approach implemented so far: *Level* 1: Innovation enabling topics; *Level 2*: LLs procedures, to assess their processes, impacts and implementations, by a reflective monitoring guide designed to create a continuous loop of observations, reflections and actions to improve the operation of the LLs and the deployment of the innovations; *Level 3*: Impact-oriented result indicators, to assess the project results. In this perspective, a suitable adaptive evaluation approach [28] for LLs is required to include multi-dimensional and multi-actor perspectives, supporting the different steps of a collaborative decision-making process and improving the potential of an open innovation context. Social Multi-Criteria Evaluation (SMCE) has been characterized as highly pertinent for addressing the concept of a "sustainable economy" [29] and implementing "circular processes" with related feedback loops (Fig. 2).

Etxano & Villalba-Eguiluz [30] highlight three primary reasons for considering SMCE's relevance in the context of sustainability: it actively incorporates the principle

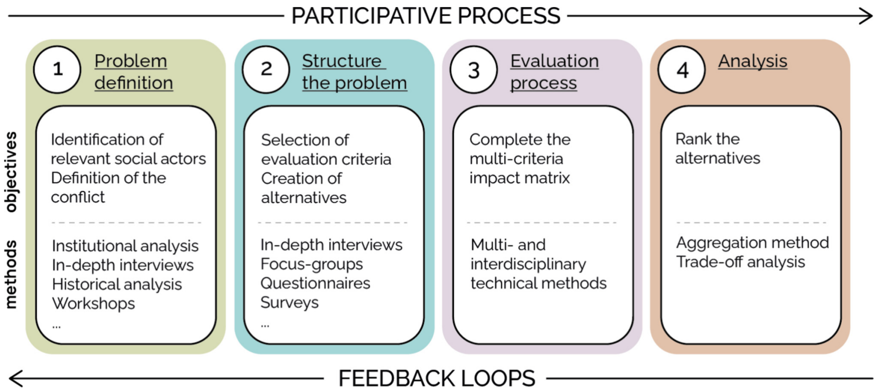

Fig. 2. SMCE process by steps. Adapted by Etxano & Villalba-Eguiluz [30].

of strong sustainability into the decision-making process, by including different criteria with both qualitative and qualitative metrics; it emphasizes participatory processes thanks to multi-group equity analysis; it seeks for compromise solutions. This last point is of particular significance, especially for ULLs, which involve negotiations between different ideas and points of view in compromise solutions. Traditionally, addressing equity concerns in Multi-Criteria Decision Analysis (MCDA) relied on adjusting criteria weights or introducing ethical evaluation criteria. NAIADE [31] has been the first method to implement SMCE, utilising an equity matrix for social evaluation. This analytical tool sheds light in the decision-making process, providing insights into where various stakeholders stand regarding each evaluation alternative. It also identifies groups that stand to benefit or lose the most. Consequently, conducting a conflict analysis through the equity matrix, it contributes to pursuing socially oriented compromise solutions. This approach presents a distinct advantage in decision-making processes. SOCRATES [32] is an evolution of the NAIADE method that implements the participatory approach using an open-source evaluation method in sustainability assessment for European policies. It can be considered suitable for ULLs and useful to support a Collaborative Decision-Making Process consistent with the circular economy perspective and oriented to build a community-driven enhancement of cultural heritage.

3.2 The Heritage Communities Urban Living Labs (HeCo-ULLs) Approach

The proposal aims to foster interaction between ULLs and cultural landscapes for supporting the building of Heritage Communities and consists of three main iterative phases (Fig. 3). Embedding the SOCRATES method into a ULL process involves integrating it into the various phases and stages to guide the lab's activities and enhance sustainability assessment and actors' cooperation means to identifies the main phases of a Collaborative Decision-Making Process able to implement circular economy principles for Heritage Communities building.

Therefore, the proposal of a Heritage Communities Urban Living Labs (HeCo-ULLs) approach has been articulated in the following phases:

Fig. 3. Phases and steps of the Heritage Community Urban Living Lab (HeCo-ULL) (authors' elaboration).

1. *Preparation phase: Stakeholder Engagement*: use SOCRATES to identify key sustainability indicators relevant to the stakeholders' concerns and actor main groups for the equity analysis. Collect baseline data on these indicators as part of the stakeholder engagement process; *Site Selection*: Evaluate potential living lab sites using SOCRATES criteria, considering factors like ecological impact, social cohesion, and economic development; *Resource Management*: apply the SOCRATES framework to assess the sustainability of funding sources and resource allocation for the ULL.
2. *Activation phase: Infrastructure Setup*: designing and constructing ULL facilities with sustainability principles, adhering to SOCRATES eco-efficiency and resource management indicators; *Data Collection and Documentation*: utilising SOCRATES as a structured framework for data collection, categorising data into economic, environmental, and social dimensions; *Community Involvement*: engaging the community in sustainability awareness campaigns and workshops based on SOCRATES principles. Encourage community members to participate in data collection and sustainability assessments; *Co-Design and Research:* collaborative design carried out by partners with academic institutions and researchers to make proposals and conduct studies on the places of the cultural landscape using SOCRATES criteria; *Evaluation:* implementing SOCRATES evaluation tools (impact assessment and equity analysis) to assess the sustainability performances of the ULL. Compare data with baseline measurements to track progress over time. Begin by incorporating sustainability goals and indicators from the SOCRATES framework into the lab's mission and objectives. At this stage, a selection of general objectives and meaningful indicators describing the environmental, social, economic, and cultural characteristics of the project/strategy goals must be identified, and a decision tree must be developed; *Heritage Preservation Initiatives*: applying SOCRATES to assess the sustainability impact of cultural heritage preservation efforts, considering economic, environmental, and social dimensions.
3. *Learning phase: Feedback Loops*: continuously gather feedback from stakeholders on sustainability-related issues, using SOCRATES as a framework for discussion and analysis of the different points of view; *Knowledge Sharing:* share sustainability findings and best practices with other communities and ULLs, emphasising using

SOCRATES for assessment and benchmarking; *Long-Term Sustainability:* develop a sustainability plan based on SOCRATES indicators to guide the ULL's long-term strategies and ensure ongoing assessment.

Depending on the case, the time frame available for the ULL may influence the different phases, the level of depth of work in each step, and the final outcomes of the Collaborative Decision-Making process. Therefore, it is essential to define the time and economic resources available in the first stage of the process.

4 Conclusions

The ULLs are dynamic spaces for cross-scale collaboration and sustainable urban development. They can support national-level objectives outlined in the Italian National Recovery and Resilience Plans (PNRRs) by providing platforms for innovation, stakeholder engagement, and sustainable urban development. Through experimentation and collaboration, ULLs enable the testing and implementation of innovative solutions to urban challenges, aligning with PNRR goals of fostering economic growth and resilience. By engaging diverse stakeholders in the co-creation process, ULLs ensure that PNRR objectives reflect local needs and priorities, enhancing the effectiveness of national strategies. Furthermore, ULLs contribute to capacity building, knowledge sharing, and evidence-based policymaking, supporting PNRR objectives related to building institutional capacity, promoting innovation ecosystems, and enhancing different form of governance structures. Despite the challenges of such processes, ULLs can be dynamic environments for translating national-level priorities into actionable strategies at the local level, driving inclusive and sustainable urban development.

Specifically, the implementation of ULLs can be considered a tool to implement the Sustainable Development Goal 11 (SDG 11), which aims to make cities and human settlements inclusive, safe, resilient, and sustainable. Literature shows that urban living labs serve as collaborative platforms engaging diverse stakeholders to co-create solutions for sustainable urban development, emphasizing the conservation and integration of cultural heritage into urban environment, thereby fostering inclusive and sustainable urbanization (SDG 11.3). By preserving and revitalizing historical sites, traditions, and innovative community practices, ULLs contribute to safeguarding cultural heritage and promoting cultural diversity, key components of sustainable cities (SDG 11.4). Additionally, they integrate landscape management strategies to enhance environmental quality and resilience, such as incorporating green spaces and sustainable land use practices, addressing aspects of SDG 11.7. Thus, through fostering innovation, knowledge sharing, and ensuring access to public spaces, these living labs further contribute to creating inclusive, safe, and accessible urban environments in alignment with SDG 11 objectives. Building mutual trust between actors and stakeholders can give the ULLs environment the characteristics of a place of knowledge and mutual learning, co-creation, co-design and co-evaluation. The circular HeCo ULL methodology presented in this paper bridges theory and practice, integrating local knowledge, a community-driven approach, and the Social Multi-Criteria Evaluation (SMCE) with the SOCRATES method for systematic cultural heritage diffusion and the heritage impact evaluation on the communities. It has a holistic approach by considering various dimensions of sustainability, including environmental, social, and economic aspects, whose view is crucial to understanding the interdependencies between different components of the cultural landscape. Furthermore, the participatory nature of SOCRATES aligns well with the need for inclusive decision-making and co-creation of sustainable solutions and encourages cooperation between experts from various disciplines. This method incorporates scenario analysis, allowing for exploring different future scenarios and their implications. Indeed, ULLs often require scenario analysis and transdisciplinary research from collaboration between urban planners, social scientists, environmental experts, and more. SOCRATES facilitates such collaboration by providing a framework with an equity analysis and a transparent approach to exploring the actors' conflicts, adapting to different contexts and scales. ULLs vary widely in terms of their focus, size, and goals, and so SOCRATES can be tailored to suit the specific needs and characteristics of each decision context by combining both quantitative and qualitative knowledge. The SOCRATES method's participatory, flexible and adaptable nature makes it well-suited for ULLs, including three main phases (preparation, activation, and learning), emphasizing holistic development through heritage preservation, community engagement, and sustainability perspective, making operative a circular design process. Key elements embrace stakeholder engagement, the quintuple helix model, circular design, collaborative research, and a long-term sustainability plan. Adaptation on a case-by-case basis is crucial, with continuous commitment until the heritage community becomes autonomous. In perspective, the research aims to test the HeCo ULL methodology in a ULL activation for the cultural landscape in the Campi Flegrei area, in Naples, to support the building of a local heritage community.

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Prediction and Uncertainty in Social Impact Evaluation: A Classification Framework

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Abstract. Predicting social impacts supports strategic decisions for Programs, Plans, Processes, and Projects (PPPPs) aligned with Sustainable Development Goals. The focus on social impact in urban and territorial policies necessitates ethical responsibility, addressing spatial justice, territorial cohesion, participatory processes, and social groups involvement. Urban and territorial contexts, conceived as open systems, can add complexity to the unambiguous identification of target areas, beneficiaries, or defined time intervals, increasing uncertainty, especially in social impact predictions. The rise in social impact assessment models, often adapted from environmental assessments, conflicts with the uncertain nature of social impacts in PPPPs. This leads to a need for open and incremental research approaches. This article explores the links between social impacts and uncertainty in the impact evaluation process in PPPPs contexts. The methodological approach defines a classification framework identifying four main uncertainty factors: Process uncertainty, encompassing Impact Categories, Impact Attributes, Causal Pattern; Context uncertainty, including Main Attributes of Complex PPPPs to explore the heterogeneity of impacts and the complexity of cause-and-effect networks in social impact evaluations of PPPPs.

Keywords: Territorial sustainable development · Urban strategies · Learning process

1 Introduction

In the context of urban studies and disciplines that contribute to Territorial Sustainable Development (TSD) [1], the concepts of 'impact' and 'impact assessment' are crucial for the evaluation process. Usually, these topics revolve around the desire to understand the cause-and-effect relationships between actions and long-term effects [2]. However, the high degree of uncertainty characterising TDS processes often requires an expansion of the perspective beyond a mechanistic approach [3]. In accordance with Sustainable Development Goals (SDGs), especially with Goal 11, impact prediction is a crucial means of supporting strategic decisions for Politics, Plans, Processes, and Projects (PPPPs) [4, 5].

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The research focuses on Social Impact (SI) for its significant role in urban and territorial policies [6], in an ethical perspective towards the future and positive social change [7]. In particular, SI relates to spatial justice, territorial cohesion, participatory processes and the involvement of social groups in practices and projects for urban regeneration [8].

Urban and territorial contexts, conceived as open systems, can add complexity to the unambiguous identification of target areas, beneficiaries, or defined time intervals, leading to increased uncertainty, especially in predicting social impacts. Weber [9] states that events are never the result of a single cause, and reality cannot be described based on clear linear relationships. Abbott [10] highlights two types of uncertainties in relation to the process and to the context. The first type relates to the unpredictability of process developments, while the second is linked to the inability to get enough control over a given setting to predict the context response. The literature on social, socio-economic, and socio-environmental impacts, and risk analysis examines various uncertainty factors, arising from uncertain operational and administrative contexts [11], the uncertain nature of the evaluation object [12], the complexity of mechanisms producing certain types of impacts [13], or the difficulty of assessing and measuring them clearly [14].

The growing focus on the social dimension of impact has led to a notable increase in models developed for Social Impact Evaluation (SIE) [7], often adapted from environmental impact assessments or originating from fields such as finance, social research, medicine, or education.

To support practitioners and decision-makers, numerous attempts have been made to define frameworks that classify tools, methods, and approaches for SIE [15–17]. However, widely used methods lean towards a clear, precise, and efficient definition of the predicted or generated impact, contradicting the inherent uncertainty of impacts. The need for predictions encourages the use of Causal Knowledge Systems (CKS) [18], processing models and interpreting large amounts of data to produce knowledge about the nature of complex causal relationships [19].

This research highlights how this trend misaligns with the uncertain nature of social impact in PPPPs, urging the adoption of open and incremental research approaches. In this perspective, conceiving SIE as a Learning Process (LP) [20] could enable the understanding of knowledge as the outcome of an incremental, iterative, and cyclical process built over time, focused on field practice, feedback collection, monitoring, and information sharing. CKS and LP complement each other in building knowledge about complex and uncertain urban phenomena. The choice between them should depend on the evaluation purpose and the uncertainty factors in the evaluation context.

This contribution explores the interconnections between social impacts and uncertainty in SIE related to PPPPs. Specifically, it proposes the development of a classification framework, providing a clear overview of uncertainty levels and factors, and facilitates the understanding of the heterogeneity of possible impacts and the complexity of cause-and-effect networks described.

The paper proceeds as follows: Sect. 2 clarifies the methodological approach; in Sect. 3, the key issues that have emerged from literature regarding uncertainty and social impact allowed for the methodological proposal to be outlined. Lastly, Sect. 4 provides discussion and conclusions on the explored topics, highlighting possible applications, limitations, and future developments of the research.

2 Materials and Methods

The necessity to analyze the relationship between uncertainty and social impact within the realm of PPPPs led to the development of a classification framework. This involved reviewing literature from scientific journals, referencing urban studies and urban sociology, reports by institutions or companies that have direct experience in Urban Policies or Corporate Social Responsibility Reporting, as well as European and national regulations on SI assessment.

This review allowed the selection of various levels and factors influencing the choice of the best methodology for impact assessment and the overall approach.

The research approach has been structured to build this classification framework as shown in Fig. 1:

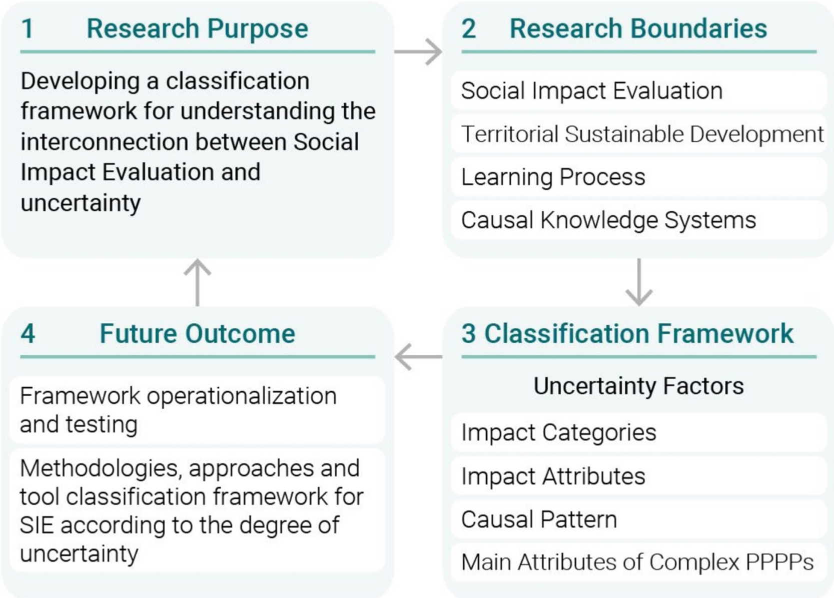

Fig. 1. The research approach

According to the main research goal, a literature review has been conducted from heterogeneous contributions, categorised and selected thematically. This enabled the identification of the main uncertainty issues in impact assessments, identifying the 4 main uncertainty factors concerning the ways in which the Learning Process and CKS were addressed, which relate to the way we understand the relationship between actions taken and social impacts: (A) Impact Categories; (B) Impact Attributes; (C) Causal Pattern; (D) Main Attributes of Complex PPPPs. Subsequently, future outcomes and developments of the framework were identified, mainly oriented towards clarifying how an impact assessment approach can be selected in relation to the type of uncertainty involved.

3 Results

The challenges arising from the interconnections between social impact and uncertainty in the context of PPPPs are numerous and intricate, necessitating flexible approaches and a profound awareness of the peculiarities of urban contexts.

Conceiving SIE as a cognitive process capable of enhancing awareness of the context and of the dynamics triggered by proposed PPPPs, the proposed classification framework identifies four main uncertainty factors: Impact Categories, Impact Attributes, Causal Pattern, Main Attributes of Complex PPPPs.

3.1 Impact Categories

The Impact Categories highlight the heterogeneity of impact types and the uncertainties that characterise them. Selected papers from the conducted literature review on impact assessments [21–24], which also spanned beyond urban studies, identified eight impact categories. The first four hierarchical categories describe levels of increasing evaluation complexity. The subsequent four, not hierarchical, express the diversity of uncertainties to be considered in relation to the social dimension of sustainability.

The initial four categories are derived from EU and national directives [25, 26] related to Environmental Impact Assessments, but they are also relevant in the context of SIE:

– *Direct Impacts*, defined as the effect of PPPPs on the direct beneficiaries target previously identified. This is the easiest level of impact to be predicted, as they are characterised by a direct and unambiguous relationship between the planned actions and the effects produced in the specific intervention context. They are generally identified and measured based on the effects produced over the medium and long term with the starting objectives of PPPPs.
– *Indirect Impacts*, defined as the effect of PPPPs on indirect beneficiaries, are second-order effects generated by direct changes to PPPPs target. These impacts are characterised by greater evaluation complexity and uncertainty compared to direct impacts, as they assume a good understanding of both the broader context and the mechanisms through which effects occur from the triggered actions. They often escape impact evaluations that are highly focused on performance analysis and program accountability, as they require knowledge of effects on the broader context.
– *Cumulative Impacts*, defined as additional effects resulting from the combination of multiple causes that affect the same target. They constitute the delta of produced changes [27, 28], where the generated effects are greater than the sum of the effects that would have resulted from a single action. Cumulative impacts can occur in particularly complex PPPPs, where numerous actions and different types of direct and indirect impacts are foreseen. They can also be generated by the combination of internal and external causes to the specific context or actions resulting from different PPPPs operating in the same context. The evaluation of this category requires a

thorough understanding of both specific and broader context, not only in reference to the evaluated PPPPs but also to other ongoing processes and dynamics that could influence the observed target.

– *Synergistic Impacts*, unlike cumulative impacts, are not only characterised by a greater delta of change, but also consider the chance that a resulting system of causes may synergistically generate one or more effects that are totally different from those predicted. This makes them the most complex impacts to evaluate, as it is difficult to trace the cause-and-effect system and to demonstrate the causality of these impacts without a specific connection implemented PPPPs. Additionally, these types of impacts depend on the specific case under consideration.

The remaining four categories stem from assessments and SIE in various application contexts. These categories can interact among themselves and with each of the four previously mentioned categories, introducing additional levels of uncertainty and predictive complexity. The four categories are:

– *Perceived impacts*, that analyse effects based on the involvement of stakeholders at multiple levels, both directly and indirectly [29]. Perceived impacts are inherent to SIE and do not directly concern the causal link between action and impacts but rather the perception of effects from stakeholders' point of view. The perceptual component and the system of social values, interests, and needs, as well as the ways in which PPPPs are proposed, can influence the success of PPPPs in an unpredictable and subjective manner. This necessitates the adoption of a realistic approach to SIE [30] or the implementation of tools and methodologies for collecting feedback from the involved social groups (questionnaires, interviews, surveys, focus groups, etc.).
– *Counterfactual impacts*, evaluated as the difference between the observed change and the effects that would have occurred in the specific context regardless of PPPPs. They characterise an experimental approach in SIE [31], within the social sciences or medical research, and they assume the possibility of clearly identifying the reference target for comparison with a second statistically similar group. In urban studies, this approach may be analogous to comparative research on similar contexts and to the study of practices, models, and design solutions. These impacts are particularly complex to assess in the case of heterogeneous and dynamic contexts or in very specific contexts.
– *Most significant impacts*, defined as substantial or potentially substantial changes [32] generated under any of the conditions characterising the specific context and the direct target of PPPPs. They are crucial in impact assessment concerning particularly fragile systems or e.g. in relation to the previously mentioned cumulative impacts. These impacts are particularly complex to evaluate as they assume a constant real-time updating of the knowledge framework and the ability to refer to quantitative standards through which to assess the significance of a change.
– *Unexpected impacts*, defined as unpredictable and highly uncertain impacts. These include all changes generated by PPPPs that after a long time, or as a result of specific research, are traced back to a system of causes, including indirect, cumulative, and synergistic effects of PPPPs. They can also be identified as impacts generated by unexpected events, sudden system changes, or catastrophes that affect the initial knowledge framework. There is no scientific evidence to generalise these approaches

to the field of SIE, nevertheless, numerous studies, such as those on Gentrification or Green-Gentrification [33], highlight how sustainability-oriented PPPPs can have long-term negative effects on social and economic sustainability.

3.2 Impact Attributes

The second element of uncertainty outlined by the classification framework involves the definition of specific impact attributes aimed at describing the qualitative nature, sometimes subjective, of SIE. Among these attributes, the following are highlighted:

– *Temporal Horizon of Impacts*, as short, medium, and long term [24]. The duration of each is not precisely defined and cannot be generalised. Moreover, many types of impacts may involve an evolution over time.
– *Positive/Negative Impacts*, evaluated according to the value system underlying the value judgement developed within the assessment process and the overall goal underlying the evaluation question. The susceptibility of the same intervention to multiple interpretations is also emphasised [7].
– *Localised/Diffused Impacts*, which represent two different ways in which a change or effect generated by PPPPs can manifest in a place. Localised impacts refer to specific and circumscribed geographical areas [34]. Diffused impacts manifest in a widespread and irregular manner, without being confined to a specific geographical area. Their distribution may appear accidental or follow an irregular pattern.
– *Temporary/Permanent Impact,* referred to the duration of the effects [35] generated by PPPPs. This temporal distinction is crucial for understanding the scope of impacts and planning appropriate management strategies. Temporary impacts occur for a limited period of time and then decrease or gradually disappear. These impacts may be associated with specific implementation phases of PPPPs. Permanent impacts persist over time even after the conclusion of PPPPs. These impacts may result from long-term structural, social, or environmental changes induced by PPPPs.
– *Intended/Unintended Impacts,* defined as the distinction between the planned or intentional effects of PPPPs and the undesired or unforeseen effects that may occur [34]. Intended impacts are positive outcomes consistent with the initial objectives aimed at achieving, while unintended impacts are negative or unforeseen effects that may occur during or after the implementation of PPPPs.

3.3 Causal Pattern

Casual patterns are schemes or models that describe cause-and-effect relationships within a system. In PPPPs, these models highlight the challenges in evaluating social impacts, both in the precise identification of causes, contributing factors, and impacts, and in describing the linear and non-linear relationships among them. Understanding these patterns is essential for an accurate and effective assessment of outcomes and effects within the realm of social impacts.

Stern et al. [36] identify four basic patterns that prove useful for describing social impacts:

– *One to One:* each cause generates a direct impact;
– *One to Multiple*; each cause generates multiple direct impacts;

– *Multiple to One:* multiple causes generate one impact, e.g., cumulative or synergistic impacts;
– *Multiple to Multiple:* multiple causes generate multiple impacts, with a high degree of uncertainty and unpredictability.

3.4 Main Attributes of Complex PPPPs

The last analysed factor concerns the uncertainty related to the context. Stern et al. [36] identify nine 'Main Attributes of Complex PPPPs' that can influence the degree of multidimensional complexity and the level of evaluation uncertainty resulting from it. For each of these attributes, some design implications have been identified that can influence the methods and strategies for implementing social sustainability in PPPPs in complex contexts.

For this research, selected attributes have been divided into two main groups:

- *Attributes related to the PPPPs to be implemented*, including the degree of specificity of the intervention (centrally specified/locally customised); the degree of standardization of interventions (standardized intervention/diversified interventions); the degree of universality of the mechanisms through which change is intended to be triggered (universal mechanisms/different causal mechanisms operating in different contexts); the degree of predictability of effects (pre-identified effects/emergent effects).
- *System attributes*, related to the operating context, the target reference and the generated impacts. These attributes may include: the degree of openness of the system (bounded/embedded); the degree of predictability of the impacts to be evaluated (predictable and linear impact/difficult to predict and non-linear impacts); the degree of interdependence of causal links (single or few causal strands that are independent/multiple causal strands that are interdependent); the degree of interdependence between causes and effects (causes and effects are independent from each other/causes and effects influence each other); the degree of homogeneity of the observed variables (homogeneous system/nested diversified system).

4 Discussion and Conclusions

The conducted research highlights a heterogeneous array of factors influencing the multidimensional and multilevel uncertainty of impact within the context of SIE for PPPPs at various intervention scales. The structured classification framework aids in navigating this intricate landscape, aiming to guide impact evaluation design choices and enhance the effectiveness of PPPPs in contributing to the social dimension of sustainability. While national and international regulations, as well as operational contexts, tend to favour criteria that simplify impact complexity (measurability, predictability, evaluation speed), the research results underscore the need for a more attentive and in-depth impact culture through a revision of commonly used tools, methodologies, and approaches.

This research clearly highlights the complexity of uncertainty and impact assessment issues, unlike the literature produced so far on the subject. However, the need for operationalisation of this framework to support practitioners remains to be addressed.

The future developments of the research will be oriented towards the operationalization and testing of the framework, tied to an in-depth exploration of experimental case studies and operational tests. To do so, it would be beneficial to define scales for measuring the level of uncertainty and the level of complexity inherent in impact assessment, as well as to classify existing methods on the basis of the degree of uncertainty and the type of uncertainty they are able to address. The underlying objective of the classification framework, indeed, is to identify the most suitable evaluation method and approach with respect to a given investigation context. Also, starting from a comprehensive literature review, aims to develop a classification framework for tools, methodologies, and approaches structuring a SIE based on the degree of uncertainty.

In conclusion, the research proposes a methodological approach to SIE grounded in a 'processual use of evaluation' [37], putting the contribution of impact assessment at the core of stakeholders' cognitive, behavioural, and organizational changes and in the identification and implementation of benefits generated in territories [38]. This approach can foster the development of PPPPs based on incremental and dynamic Learning Processes [20], capable of learning from mistakes, progressively increasing awareness of operational contexts and mechanisms for generating positive social change, and aiming towards the sustainability of cities, territories and communities.

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A New Tool for Assessing Sustainable Mobility at the Neighborhood Level: Methodology and Application

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Abstract. The objective of the current work is the construction of an assessment tool capable of evaluating the level of sustainability, specifically from a transportation standpoint, at the neighborhood level. The tool comprises various quantitative indicators, some derived from existing neighborhood assessment models, while others have been developed specifically by the authors. Each component of the tool is designed to evaluate a single aspect of the transportation supply system: 1) vehicular motorization; 2) walking mobility; 3) bicycle mobility; 4) transit. We validate the proposed model through its application to assess how the sustainability of the transportation supply system in a neighborhood in Cagliari, a mid-sized city in Italy, changes after a structural intervention involving the introduction of a new light rail line.

Keywords: SDG11 · sustainable mobility · neighborhood assessment · light rail

1 Introduction

Sustainable transportation plays a key role in achieving the 2030 Agenda for sustainable development, with its impacts across a number of Sustainable Development Goals (SDGs) [1]. Particularly, SDG 11, which aims to "make cities and human settlements inclusive, safe, resilient, and sustainable" [2, 3] underscores the importance of sustainable transportation in shaping urban environments [1]. This is because the design and implementation of sustainable transportation systems, such as transit, and the development of pedestrian- and cyclist-friendly infrastructure, can help minimize environmental and climate change impacts, promote universal access, ensure safety and improve overall quality of life.

In this context, different national and regional strategies have been implemented [4], with the aim of identifying a set of objectives and actions to guide policymakers in implementing policies toward SDGs, including SDG11. Nevertheless, most of the indicators concerning sustainable mobility proposed in these strategies are formulated at a national or regional scale [5], while it would be important to also run analyses at the neighborhood level [6, 7]. For example, in the case of the Sardinia Region, context of the current study, the proposed indicators in terms of sustainable mobility refers only to

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the city or the regional dimension, overlooking the unique challenges and opportunities within each neighborhood [8]. Instead, the contextualization and scalability of indicators at the neighborhood level would permit to assess the sustainability of transportation systems of a specific urban area in more tailored manner, taking into account its specific characteristics [7], so as to help policymakers make decisions and implement targeted interventions that genuinely promote sustainable mobility and contribute to the actual achievement of SDG 11.

Some Neighborhood Sustainability Assessment (NSA) tools (*e.g.*, LEED, BREEAM, ITACA), designed to evaluate and enhance the effectiveness of infrastructural interventions at the local level, incorporate metrics related to sustainable mobility at the neighborhood scale. However, they face some challenges. Firstly, they often adopt a one-size-fits-all approach, whereas the model should be scalable to different local contexts. Secondly, certain tools prioritize specific transportation modes over others, despite the fact that achieving sustainability requires the balanced development of all environmentally friendly modes. At the same time, prior research in the fields of transportation and urbanism has sought to introduce diverse indicators for assessing sustainable mobility. Examples include the computation of primal and dual accessibility indicators [9], including detailed analysis of walkability [10–14], and cyclability [15] [16]. Additionally, proposals have been made for metrics to evaluate the performance of transit services [17, 18]. However, these indicators are often overly complex and may present challenges for policymakers and practitioners in terms of comprehension and utilization.

In the current work, we aim to propose an assessment tool capable of evaluating the level of sustainability, particularly from a transportation standpoint, in a neighborhood. The tool is designed to be scalable to different contexts, consider the diversity of transportation means available to each citizen, address the needs of individuals with different characteristics, and be user-friendly for planners and policymakers. To demonstrate the validity of the tool, we apply it to a case study in the city of Cagliari, Italy. Specifically, we use the model as a tool to make evaluation of the sustainability status of a neighborhood before/after the implementation of a new light rail line.

The remainder of the paper is organized as follows: In Sect. 2, we provide an overview of the indicators currently proposed by some Neighborhood Sustainability Assessment tools. In Sect. 3, we describe the proposed tool and the methodology employed to compute each indicator included in it. Moving to Sect. 4, we present the results of the tool's use test in the context of our case study. Some key conclusions are drawn in Sect. 5.

2 Overview of Existing NSA Tools

In literature, there are different tools for assessing the sustainability level of a neighborhood in terms of transportation supply, coming from different countries. These tools rely on a set of indicators grouped into categories that represent different aspects of sustainability and each indicator might be assigned points based on how well a neighborhood performs in that specific area [19, 20]. The following tools have been considered for the current analysis: BREEAM [21], HQE2R [22], STAR [23], ITACA [24], LEED [25].

In terms of the private transportation system supply, the only protocols addressing this theme are ITACA and HQE2R. Specifically, ITACA provides indicators of road connectivity (road network connectivity, road network cyclomatic complexity, road network scale) and assigns a score to the neighborhood based on their values. HQE2R uses a different approach and suggests measuring the quality of the road network based on the average speed required for a car journey from the city center to the reference neighborhood.

Regarding accessibility to public transport, the protocols provide different types of indicators, mainly based on the location of stops, the frequency of public transport vehicles at stops, the location of housing units, and the description of the pedestrian network. BREEAM, LEED, and ITACA suggest that the design of a new neighborhood/housing core should be positioned along an existing public transport line. STAR proposes increasing the number of families with access to public transport, without providing any reference to the percentage increase to achieve. In terms of indicators, LEED and ITACA assign a specific score based on the number of housing units within a 400m walking distance (along the pedestrian network) from a public transport stop and the service frequency at that stop. In contrast, BREEAM does not suggest a specific distance but provides a score based on it (maximum score for a 500m walking distance). HQE2R uses a different distance threshold (800m) and, instead of buildings, uses the number of families as a reference. The only protocol to provide a score based on the type of public transport stop is BREEAM. In addition to the above indicators, HQE2R also recommends calculating the average travel time to work by public transport, the percentage of the lowest 20% of the population's average salary dedicated to travel expenses in public transport, and the kilometers of preferential lanes per 100,000 inhabitants. However, it should be emphasized that HQE2R's suggested indicators are on a city scale, not a neighborhood scale.

In terms of walkability, ITACA provides a score based on an indicator that computes the percentage of neighborhood pedestrian paths following the principles of "Design for All". Similarly, BREEAM provides a score based on the percentage of streets designed to prioritize pedestrians (home zones street). HQE2R recommends calculating the percentage of the city/neighborhood area occupied by safe pedestrian paths. Also, LEED provides various indications regarding the walkability of streets. STAR indicates that the goals of a new neighborhood project should include increasing the extension of sidewalks, although it provides no numerical indication of this increase.

We turn our attention on indicators concerning bikeability. ITACA provides two different indicators: linear meters of safe bike paths per inhabitant, the extension of the bike network compared to the total road network. Following a similar philosophy, the HQE2R protocol suggests calculating the kilometers of bike paths per km^2 of urbanized area and the kilometers of bike paths per 100,000 inhabitants. The LEED protocol indicates the percentage of residential and non-residential units (50%) that must be located near a bike path with an extension of at least 4.8km. BREEAM, on the other hand, does not provide any numerical indicator but assigns a score based on the presence or absence of bike paths in the neighborhood. Like the previous themes, the STAR protocol does not provide any numerical indicator but generally talks about increasing bike paths. In terms of additional services for bikeability, BREEAM indicates that for non-residential buildings, the number of bike parking spots should be 50 for every 500 people with access to the building. The LEED protocol also provides some prescriptions on the number of bike parking spots based on the number of people living in the building.

Regarding shared mobility, LEED prescribes that 50% of residential and non-residential units in the project should be within a maximum distance of 400m from a sharing service (bike, car, scooter). ITACA provides a score based on the percentage of the population within 400 m of at least one bike-sharing station (no reference to car sharing is made).

Another type of analysis suggested by the different protocols is the accessibility of the neighborhood residents to various types of activities and services. In particular, BREEAM provides a score based on proximity to different types of services but does not give any indication of the percentage of buildings that should be located around each service. On the other hand, STAR prescribes the analysis of destinations within 500 m of the project boundaries but does not provide any numerical indication. Unlike the two previous protocols, ITACA and LEED provide more detailed indications. ITACA provides a score based on the following indicators: (1) percentage of the population within 400 m of at least one service facility and one commercial facility; (2) percentage of the population within 400 m of at least one sports facility and one cultural facility. The LEED protocol goes into more detail on this issue and prescribes that: (1) 90% of housing units be within a walking distance of 400m from a public space; (2) 90% of residential and non-residential units be within an 800m walking distance from a recreational area of at least 2325m^2; (3) 50% of housing units be 800m from an elementary-middle school and 1600m from a high school; (4) at least 70% of housing units must have a green space within an 800m walking distance; (5) 50% of residential buildings be within a 400m walking distance of a certain number of services; (6) the number of residential buildings is equal to 30% of the total building area; (7) the project is implemented in such a way that from its geographical center within an 800m radius, a number of jobs at least equal to the number of housing units in the project can be reached.

From the analysis reported above, it emerges that often the indicators provided by different protocols are similar to each other, both in terms of formulation and the data required for calculation. In many cases, numerical indicators are provided, but not the indication of the value to be achieved for the neighborhood to be considered sustainable. In others tools, goals to be reached are provided, but these are often rather general goals that do not provide any detailed indication to the planner on how to achieve them. For this reason, in the current paper, we want to propose a model capable of providing, at the neighborhood level, indications on the current state of sustainable mobility: 1) that encompasses all components of transportation, from public transport to shared and active mobility (walking and cycling); 2) that includes a level of detail such that planners know exactly where localize their interventions; 3) that uses indicators that are easy to calculate and immediately understandable for both policy-makers and practitioners.

3 The Proposed Tool

In the current study, the theme of sustainable mobility at the neighborhood level is addressed with an analytical tool that involves the computation of various indicators, each related to different modes of transportation: 1) vehicular motorization; 2) walking mobility; 3) bicycle mobility; 4) transit. We employed a multi-step process to arrive at the final set of indicators used in the proposed tool. First, we conducted a comprehensive literature review of scientific papers, Neighborhood Sustainability Assessment (NSA) tools, and National and Regional Sustainable Development Strategies, which permitted to identify an initial set of 78 potential indicators. From the initial set, we further refined the indicators based on two key criteria: feasibility and meaningfulness. Specifically, we assessed the feasibility of calculating each indicator based on data availability at the city level for our case study, as suggested in the work of Lami *et al.* (2023) [26] and we evaluated the uniqueness of each indicator (avoiding redundancy) and its relevance to the specific scope of the tool, as well as is spatial and temporal scalability [27]. In addition, we included some indicators that were formulated ad hoc for our tool. The resulting set of indicators was then submitted to public administration and stakeholders for their feedback in one in-person meeting. This collaborative process helped us arrive at a final set of 18 indicators that are both easy to compute and address the key aspects of sustainable mobility at the neighborhood level. For example, one result of this process was the decision not to include indicators expressing the linear extension of walking and cycling infrastructure in our tool. This decision was made because they were redundant and less informative compared to indicators measuring the surface dedicated to these categories of users (linear indicators do not provide an idea of the spaces). Additionally, they lacked the information provided by the accessibility indicators in terms of reachable places. The complete list of all 18 indicators, along with their descriptions, units of measurement, and references, is provided in Table 1.

4 Case Study

4.1 Description of the Context

The chosen context to test the proposed model above is the neighborhood of Sole/La Palma in the city of Cagliari, main city of the region of Sardinia (Itay). Established in the 1960s as part of the INA-Casa and PEEP initiatives (Piani di Edilizia Economica e Popolare - Plans for Affordable and Popular Housing), this neighbourhood boasts a residential character, characterized by the presence of three to four-story houses complemented by garden spaces. The area is notable for its close proximity to the Molentargius park, one of the largest wetland located in an urban area in Europe. Additionally, the neighborhood enjoys accessibility to the popular Poetto beach.

4.2 Data Collection

The proposed evaluation model considers:

1. The physical characteristics and infrastructure of mobility services associated with different modes of transportation in the neighborhood (motorized mobility, walking, cycling, public transport).
2. The potential destinations that residents or users of the neighborhood can reach.

Table 1. Description of the indicators included in the tool

Theme	Indicator	Definition	Unit measure	Reference
Vehicular motorization	Connectivity of the road network	B/A * 100, where B is the number of intersections and A is the surface of the study area	[N/km^2]	ITACA
	Road surface dedicated to vehicles	roadway surface area / total road surface area * 100”	[%]	Own elaboration
	Road surface dedicated to car parking	roadside parking area / (roadway surface area) * 100	[%]	Own elaboration
		parking area surface / total open public space area * 100	[%]	Own elaboration
	Car sharing service	Percentage of the population accessing a car-sharing service within 300 m from their residence	[%]	LEED, ITACA
Walking mobility	Road surface dedicated to pedestrian paths	road surface area of pedestrian paths / total road surface area	[%]	Own elaboration
	Pedestrian areas	surface area of squares, parks, and other pedestrian areas / total surface area * 100	[%]	Own elaboration
	Safety of the walking network	number of pedestrian crossings / length of road network with sidewalks * 100	[N/100m]	Own elaboration
	Accessibility to health services	Percentage of the population accessing a health service within 300 m from their residence	[%]	ITACA, LEED

(*continued*)

Table 1. (*continued*)

Theme	Indicator	Definition	Unit measure	Reference
	Accessibility to cultural and recreational services	Percentage of the population accessing a cultural/recreational service within 300 m from their residence	[%]	ITACA, LEED
	Accessibility to essential services	Percentage of the population accessing an essential service within 300 m from their residence	[%]	ITACA, LEED
	Accessibility to educational services	Percentage of the population accessing an educational service within 300 m from their residence	[%]	ITACA, LEED
Cycling mobility	Road surface dedicated to cycling paths	Percentage ratio of road surface dedicated to cycling paths to the total road surface	[%]	BREEAM/HQE2R
	Road surface suitable for cycling	Percentage ratio of road surface suitable for cycling (dedicated lanes and 'zone 30') to the total road surface	[%]	Own elaboration
	Bike-sharing service	Percentage of the population accessing a bike-sharing station within 300 m from their residence	[%]	LEED, ITACA
Transit	Extension of public transport lines in the area	length of road lanes affected by public transport / total length of road lanes (per direction) * 100	[%]	Own elaboration

(*continued*)

To encompass all the identified elements, various databases were utilized, some freely available through national and local authority geo-portals (National Institute of Statistics - ISTAT, the Autonomous Region of Sardinia, the municipality of Cagliari), and others

Table 1. (*continued*)

Theme	Indicator	Definition	Unit measure	Reference
	Road surface dedicated to transit lanes	surface area of preferential lanes for public transport / total road surface area * 100	[%]	Own elaboration
	Accessibility to public transport stops	Percentage of the population accessing a transit stop within 300 m from their residence	[%]	LEED, ITACA, BREEAM, HQE2R
	Quality of stops	Percentage ratio of the number of stops with a score > 2 assigned (for the presence of amenities) to the total number of stops	[%]	BREEAM

collected through consultation of web platforms such as OpenStreetMap, Google Maps, and Sardinia Open Data. Data not freely available was manually digitized.

4.3 Use of the Tools for Assessing a Pre-Post Intervention Scenario

In this section, we test the proposed model in the case of an infrastructural intervention. The intervention involves the implementation of a new light rail infrastructure in the neighborhood under analysis, connecting Poetto beach to the city center of Cagliari. Along the light rail, the intervention includes the construction of a new cycling path, the requalification of the sidewalk on Viale Poetto, and the greening of some currently unused areas facing the neighborhood (see Fig. 1).

We utilize the tool to calculate the benefits of this action. From Table 2, it is evident that, at the neighborhood level, there is an improvement in various metrics, particularly the road surface dedicated to pedestrians (from 23.16% to 27.23%) and the area designated for cycling paths (from 0.56% to 3.24%). We also observe a change at the level of space exclusively dedicated to transit (from 4.38% to 6.69%), despite the removal of bus lanes in the street object of the intervention. At the same time, there is a clear improvement in terms of the quality of stops, with more than half of the stops being provided with amenities such as information signs, benches, and lighting. In regards to safety, the index shows no changes, as the density of pedestrian crossings stayed the same despite their upgrading near light rail stops.

Table 2. Before-after evaluation of the intervention

Theme	Indicator	Unit measure	Before intervention	After intervention
Vehicular motorization	Connectivity of the road network	[N/km^2]	196.40	196.40
	Road surface dedicated to vehicles	[%]	73.50	69.53
	Road surface dedicated to car parking	[%]	10.61	10.61
Walking mobility	Road surface dedicated to pedestrian paths	[%]	23.16	27.23
	Pedestrian areas	[%]	7.57	9.38
	Safety of the walking network	[N/100m]	0.8957	0.8957
	Accessibility to cultural and recreational services	[%]	98.73	98.73
Cycling mobility	Road surface dedicated to cycling paths	[%]	0.56	3.24
	Road surface suitable for cycling	[%]	35.88	38.6
Transit	Extension of public transport lines in the area	[%]	33.44	33.44
	Road surface dedicated to transit lanes	[%]	4.38	6.69
	Accessibility to public transport stops	[%]	90.88	90.88
	Quality of stops	[%]	35.00	54.50

5 Conclusions

Within the framework of SDG11, one of the aspects that needs attention is sustainable mobility. Usually, tools used to explore the performance of an area with respect to the goals set by SDG11 in terms of transportation consist of indicators at the national and regional levels, while only a few are tailored at the neighborhood scale. In the current work, we propose a tool for the assessment of the level of sustainability of a neighborhood from a transportation standpoint. The developed model is composed of 18 different metrics, some inspired by existing neighborhood sustainable assessment tools, others proposed ad hoc, concerning the various transportation alternatives that a user can have available for their trips.

The tool was tested by employing for assessing whether the implementation of a new light rail line is able to effectively change the face of mobility of a neighborhood. The neighborhood chosen is located in Cagliari, a middle-size city in Italy. Our results

Fig. 1. Overview of the intervention

demonstrated the benefits of the infrastructural intervention, like the one implemented in the study, not only in terms of reduced travel times, as usually done by transport studies, but also in terms of areas subtracted to cars in favor of pedestrian and cyclists and increased safety.

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A Methodological Proposal to Assess Proximity in Functional Urban Areas

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Abstract. The growing awareness in the European context of the crucial role of sustainable mobility, energy efficiency and the reduction of air pollution, within the framework of the objectives of the 2030 agenda, highlights the need for gradual changes in lifestyle to achieve these goals of communities. In particular, the pandemic and the recent energy crisis, in fact, have further highlighted the need to develop integrated systems (geography/land use - transport/mobility - telecommunications/digitalisation) capable of renewing urban planning oriented towards quality of life, associated with spatial proximity. In this synthetic framework, the main objective of the manuscript is to develop a methodological approach for the construction of a proximity index based on FUAs Functional Urban Area (Copernicus project, with remotely sensed satellite data). The Functional Urban Area Proximity Index (FUAPI) considers the spatial distribution of the residential local community and the density of FUAs, with the aim of supporting the updating of urban planning, both to develop ex-ante scenarios, the decision-making process and to the localization and/or strengthening of highly attractive urban services (stadium in particular).

Keywords: Spatial Proximity · Functional Urban Area · General Services

1 Introduction

In the aftermath of the end of the health crisis, much research has given a strong impulse to the valorisation of urban sociality, on which the services strictly connected to residence and part of the general services of the city are based [1–3]. In particular, the services connected to the residence are based on proximity, or rather on the principle according to which everything needed and needed on a daily basis must be reachable within 15–20 min on foot from the residence [4–6].

In fact, spatial proximity has allowed the generation and/or consolidation of a proximity of neighborly relations, which has characterized life in cities, in Italy in particular.

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It is no coincidence that social relationships, mutual care and the valorisation of common goods constitute the main outcome of the city of proximity, the foundation of urban planning [7], where the neighborhood represents the vital part of the relationships between living and residential services.

Furthermore, in cities there are also general services, which perform functions of a higher rank than those strictly connected to residence. They are fundamental for urban functionality, such as infrastructures and public services such as technological networks (transport, energy and water); health services (hospitals, clinics, clinics); education services (universities, schools, libraries); public safety services (Police, firefighters, etc.); parks and cultural and recreational services (museums, theatres, stadiums). Furthermore, general services are those that combine the formation of the complex relationship between city form and city service - that is, the relationship of mutual influence between the physical and structural configuration and the provision and efficiency of urban services. The manuscript's research question fits into this synthetic framework: Is it possible to measure the spatial proximity of the highly attractive urban services? More generally, is it possible to measure the spatial proximity within the Functional Urban Area (FUA)?

The manuscript, that derives from a previous study conducted by the authors [8], proposes a methodological approach for the construction of the Functional Urban Area Proximity Index (FUAPI), based on the spatial distribution of the residential local community and density of urban fabric and services in the radius of 1 500 m from the place whose attractiveness is estimated (general service). The FUAPI is intended as a useful tool for developing scenarios, to support local sustainable transport & urban planning, guiding the choice of location and/or strengthening of highly attractive urban services (stadium, shopping center, etc.).

The manuscript is organized as follows: Sect. 2 provides a literature review on the concepts of FUA and spatial proximity; Sect. 3 focuses on the method; Sect. 3.1 describes the study area and Sect. 3.2 provides the related data; Sect. 4 is dedicated to the application of the method; Sect. 5 and Sect. 6 discusses respectively results and conclusions of the study.

2 Literature Review

In line with the research question (Sect. 1), the literature review focused on the concept of spatial proximity and Functional Urban Area (FUA). The health crisis emphasized the strategic role of proximity (spatial and social relations). Spatial proximity refers to the proximity - geographical or temporal - between the community and the services [20]. It plays an important role in the definition of also sport clusters' attractiveness [21]. In this sense, the planning of Sports Mega Events (SMEs) appears to be a complex process, as it includes multiple issues (definition, mediation, urban development, economy, politics, legacy.) which should respect the principles of sustainability and the goals of the 2030 Agenda (SDGs).

According to previous studies [8, 9], the dimension to assess spatial proximity is well represented by the FUA, which consists of an extended urban area based on population density in order to identify commuting, defined as Local Systems of Labor [10]. In particular, as argued by Organisation for Economic Co-operation and Development (OECD, 2014), FUA represents an aggregate of spatially contiguous municipalities, composed of a city and its commuting zone, i.e. integrated urban contexts interconnected from an economic point of view. In this sense, the OECD methodology makes it possible to compare FUA of similar size, located in European countries, based on a specific classification referring to the population. FUA and population density data can be found among Urban Atlas (UA) products, which also provide data concerning Coastal Zones (CZ), a buffer of 10 km towards the hinterland, without population estimates. The possibility to compare FUAs of similar size located in European countries, as well as the availability of open access and regularly updated data, makes FUAs the most suitable spatial dimension for the application of research methodologies in other contexts.

3 Materials and Methods

In previous authors' research the method consisted in the development of a Proximity Index to support the planning of Sport Mega Events (SMEs), calibrated on urban proximity and spatial distribution of the local community [8]. In particular, Kernel Density Estimation (KDE) was used to transform a point data model into a 3D - continuous density surface, that expresses the variation in the density of punctual events in the study area. As a matter of fact, KDE uses a three-dimensional kernel function to weight events within a radius of influence (radius parameter or threshold). The choice of the radius value depends on the nature of the data, the objective of the analysis and the characteristics of the phenomenon studied [19].

In this manuscript there has been progress in the employed method, which aims to develop a methodological approach for the construction of a proximity index based on spatial distribution of the residential local community and on the density of selected sets of elements attributed to urban functions - as specified below - identified on FUA's subunits. The proximal of a general service (Sect. 1) was then evaluated, using the following formula

$$FUAPI = \frac{1}{n}\sum\nolimits_{i=1}^{n} w_i k_i \tag{1}$$

FUAPI represents the sum (1-n) of Kernel Density Estimation areas performed over the different functions of the i-th dataset (cluster area of KDEi) and what we define as a spatial proximity, which is the buffer area with a radius of 1 500m computed from the service whose attractivity is evaluated; k_i can be described with the following formula:

$$k_i = \frac{cluster\ area\ of\ KDE_i}{spatial\ proximity} 0 \leq k_i \leq 1 \tag{2}$$

The weight, w_i represents the ratio between the difference between the population as enclosed in the spatial proximity (within 1 500 m from the service point) and the population living in the FUA's subunits interested by every function's class, divided by the population in the spatial proximity area:

$$w_i = \frac{population\ of\ spatial\ proximity - population\ of\ FUA_i\ class}{population\ of\ spatial\ proximity} \tag{3}$$

The possible scenarios are displayed in Table 1.

Table 1. Possible scenarios, classified for the respective level and FUAPI class (Authors: Balletto G. and Sinatra M, 2023)

Level	FUAPI class	Scenario
1	1–0.76	Positive
2	0.75–0.51	Average positive
3	0.50–0.26	Average critical
4	0.25–0.00	Critical

3.1 Study Area. Olbia City and the Nespoli Olbia Stadium (Sardinia, Italy)

The study area is represented by the city of Olbia, the main socio-demographic and economic growing city in Sardinia Region. In the last three years, the population increased by over 1 000 units, recording a constant growth from 2020 to 2023, exceeding the ceiling of 61 thousand residents (Fig. 1).

The increase was determined by the migration balance: both internal and foreign migration are strongly positive, a fact that confirms the great attractiveness represented by Olbia's strong economy and quality of life. This is a very different condition compared to the province of Sassari, which ranked 77th in Italy for quality of life (2023), (-8 positions compared to 2022) [11].

Among the possible explanations for Olbia's attractiveness are its vibrant economy and its material and immaterial infrastructure. The growth rate of businesses was 4% compared to 2.7% in northern Sardinia and 2.1% in Sardinia. On the infrastructural front, an important role is played by the airport, port and tourist and hospital system (Fig. 1). Olbia hosts the first passenger port in Italy and the second airport in Sardinia. Rapid economic growth has progressively led to an urban expansion characterized by a polycentric spatial structure, which often appears fragmented. In this sense, the general objective of the Local Plan (2020) [12] is precisely to connect the plurality of urban agglomerations at the different levels of the urban hierarchy, through a system of networks, such as urban and extra-urban ecological, road, vehicular and cycle-pedestrian, but also railway networks (the Airport-Port city connection represents a priority).

The integrated urban and territorial scenario will therefore be the result of different actions on the material infrastructural networks for sustainable mobility, in coherence with the mobility and transport planning tools:

- the Urban Mobility Plan (UMP, 2014) [13], a medium-long term planning tool which defines integrated actions aimed at improving the efficiency of public transport, reducing traffic, promoting sustainable transport and improving the quality of life in urban areas.
- the Bike Plan and the Walk Plan (2021), which provide strategic direction for how the City plans a quality, safe and usable cycle network and a greater pedestrian infrastructure for more people, thus encouraging sustainable mobility for daily needs and promoting a healthy lifestyle.

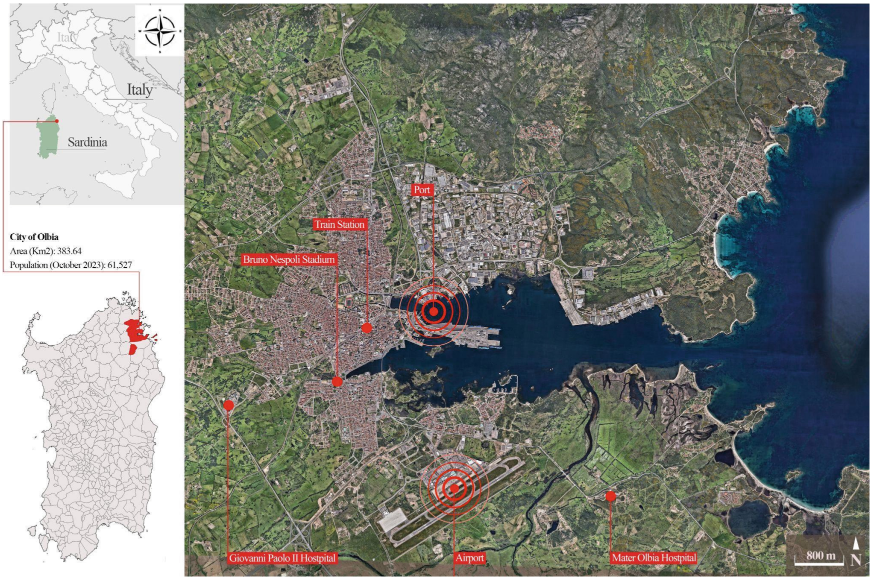

Fig. 1. The city of Olbia, in the north-east of Sardinia, Italy (Author: Ladu M., 2024).

The Bike Plan and the Walk Plan are part of the Action Plan within the European Cyclewalk project [14] financed by the Interreg Europe 2014–2020 program. The Action Plan supports the drafting phase of the new Sustainable Urban Mobility Plan (SUMP) [15] for a more livable and accessible city. Making the public transport more efficient and improving connections between the urban center and the surrounding settlements represent the main objectives of the SUMP. In this sense, the SUMP is in line with the European Commission's objectives to achieve the targets for reducing emissions, noise, pollution and accidents.

3.2 The Data

According to the literature review, the following dataset was proposed in the manuscript, as summarized in Table 2:

- Function Urban Area (FUA) or Coastal Zones (CZ) (Urban Atlas, 2018 edition). Due to Olbia's non-metropolitan status, FUA data is not provided. For this reason the CZ dataset was utilized in this manuscript (Copernicus, 2018 Edition). This dataset, among the most recent products, identifies the coastal strip considering a buffer of 10 km towards the hinterland. As vector data, the data offers comprehensive information about land cover and land use for 71 thematic classes in areas along the European coast for the reference year;
- Permanent census of population and housing (ISTAT, 2021). This dataset was used at census unit level to identify the resident population for the different land use classes.

Table 2. Datasets.

ID	Dataset	Open Data	Source
01.1	Sports and leisure facilities	✓	FUA/CZ (Copernicus, 2018 Edition)
01.2	Continuous urban fabric (IMD > 80%)		
01.3	Dense urban fabric (IMD 30–80%)		
01.4	Low density fabric (IMD < 30%)		
01.5	Industrial, commercial, public and military units		
02	Permanent census of population and housing	✓	ISTAT, 2021

4 Case Study. Case Study. Nespoli Olbia Stadium

The planning of general services with strong attractiveness represents a challenge for the management of negative externalities: traffic, pollution, noise, well being to the local community [16]. The rapid socio-economic and urban growth of the city of Olbia requires reflection on the possibility of redeveloping the current stadium or relocating it. For this reason, the Olbia stadium was selected as a case study.

For the analysis it was chosen a quadratic KDE, with a 500 m bandwidth and 25m cell-size, which represents a discrete approximation of the continuous density estimation area. After several tests, the 500 m bandwidth represented a good compromise between a too spiky representation of the phenomenon under observation and a too smoothed one. Also, such a distance is compatible with an approximate 5-min walk, therefore useful for urban geography and planning considerations - in previous research used similar values as 400 m and 300 m [17, 18].

The geospatial representations below illustrate the Kernel Density Estimation and the stadium spatial proximity (R = 1 500 m - Fig. 2a) for the following Coastal Zones: sports and leisure facilities (Fig. 2b); continuous urban fabric (IMD > 80%) (Fig. 2c); dense urban fabric (IMD 30–80%) (Fig. 2d); low density urban fabric (IMD < 30%) (Fig. 2e); industrial, commercial, public, military, and private units (Fig. 2f).

5 Results and Discussion

Following the literature review this study proposes a quantitative methodology to build a synthetic index (FUAPI) to support the updating of urban planning, to develop ex-ante scenarios and the decision-making process to the localization and/or strengthening of highly attractive urban services (stadium in particular). According to the proposed approach, the FUAPI is applied to the Nespoli Olbia stadium. The evaluation of the FUAPI refers to spatial proximity (Radius 1 500 m) of the stadium and in particular five clusters (Fig. 2) developed through the KDE. The novelty of the approach stand in the combination of the concept of proximity with methods (KDE), tools (GIS), and planning indicators (dataset proposal, Table 2). The research was based on the concept of spatial proximity, i.e. the consideration of a "buffer - service area" around the Nespoli Olbia stadium (dashed red line in Fig. 2). A mix of function and characteristics is summarized in

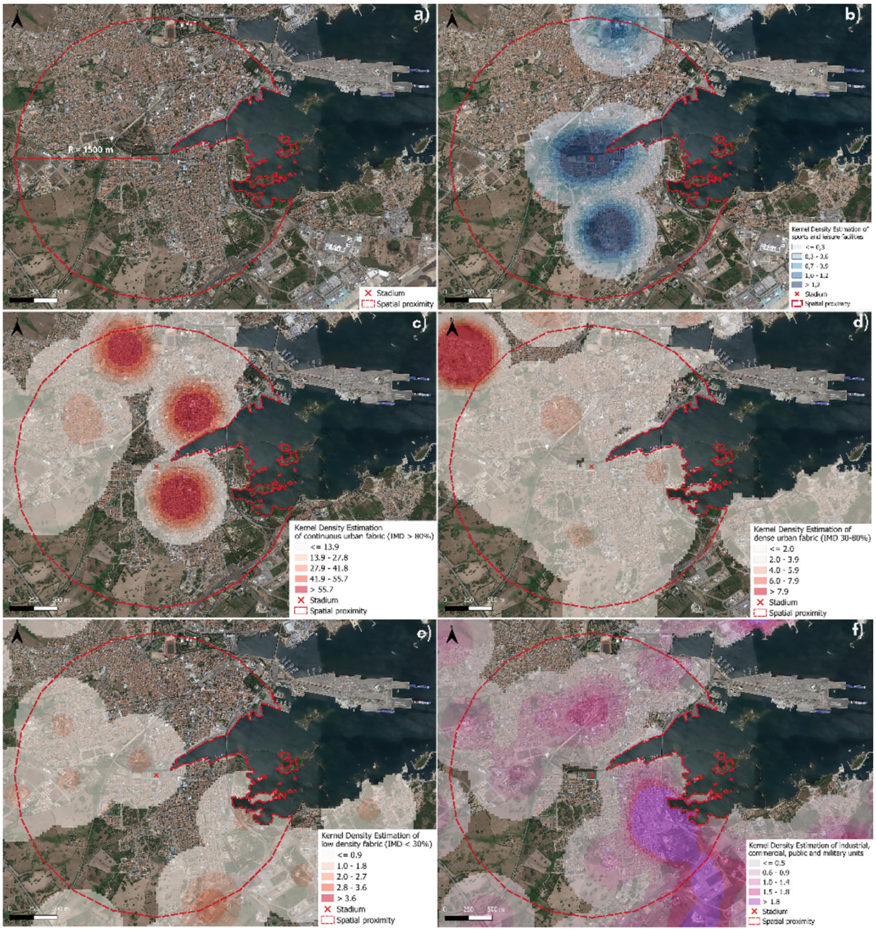

Fig. 2. Stadium spatial proximity and Kernel Density Estimation elaborations (Author: Sinatra M., 2024)

Table 3, where the results of the analyses performed in the area are presented. The FUAPI represents an Average positive scenario (level 2) which does not require significant Local Public Transport and urban design actions to encourage cycle-pedestrianism.

6 Conclusion and Future Development

The interdisciplinary approach followed in the present research aims to develop the FUAPI. A multi-layered interdisciplinary approach was in fact adopted, combining the principles of the sustainable city - in its more recent evolutions towards the 15-min city - from different points of view. As discussed above, the focus in the present paper has been on the proximity area of Olbia football stadium, realized drawing an approximately 15 min buffer zone (Radius 1 500 m) around the stadium and overlaying on that different

Table 3. Summary of the results.

Cluster (Kernel Density Estimation - KDE)	w_i	Population of FUAi	Population of spatial proximity	Cluster area of KDE (m^2)	ki	
	Sports and leisure facilities	1.00	5	61 882	2 329 810	0.37
	Continuous urban fabric (IMD > 80%)	0.73	16 484		3 825 017	0.61
	Dense urban fabric (IMD 30–80%)	0.84	9 732		5 279 944	0.84
	Low density fabric (IMD < 30%)	1.00	2		3 161 158	0.50
	Industrial, commercial, public and military units	1.00	2		4 646 289	0.74
	FUAPI = 0.55 (level 2)					

Source: our elaboration

Kernel Density Estimation on residential, activities and services. This was realized using different spatial analytical techniques, allowing gridding the study area, allowing obtaining a minimal unit of analysis where the results from the different partial indicators can be referred to. As described, in the present research a minimum unit of 25 m was used to collect and represent the results. The application of the FUAPI provides an ex-ante scenario of the Olbia stadium proximity area obtaining an Average positive scenario (level 2), which does not require significant LPT and urban design actions to encourage cycle-pedestrianism. In this sense, the synthetic index supports urban governance, in order to update urban and transport planning. The aim for future research is continue in this line and to test the method in selected stadiums for Europeans Championship 2032 by dataset of Triple Access Planning (TAP), which, is based on urban accessibility, that can be achieved through the transport system (physical mobility), the territorial system (spatial proximity) and the telecommunications system (digital connectivity). Digital connectivity, i.e. being connected, has in fact become an integral part of daily life, as important for communities and businesses as connection to service networks and therefore relevant in urban planning.

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Sociotechnical Perspectives for Data Practices. The Impact of Data-Driven Approaches to Design Theory and Action

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Abstract. This paper explores the ways data is transforming design processes, investigating its potential in shaping architectural theory. The study adopts a theoretical framework that views the architectural project as a sociotechnical entity unfolding through a network of actors and documents. By observing two selected case studies, their methodologies and tools for collection, analysis, and synthesis are described, leading to a discussion of data production, its sources, and the actions required for its application. Examining the production network that generates data, making it apt for use, ties it to its evolving significance for architectural theory and practice. The apparent objectivity regarding data applications is then critically examined, letting the socially embedded nature of its practices emerge. Ultimately, data represents a challenge for architects to reflect on their role and competence in a network of actors.

Keywords: Data Practices · Sociotechnical Studies · Architectural Project

1 Introduction

In the evolving intersection of architecture and data applications, this paper delves into exploring of how data integration transforms the design process. The research aims to investigate what data can offer to the understanding of architectural processes. As the relevance of data in architectural decision-making becomes increasingly pronounced, the paper scrutinises the multifaceted applications of data in addressing urban challenges. Laboratories and research centres actively contribute to this transformation, crafting advanced tools tailored to facilitate meaningful changes in urban design [1, 2].

While research on data practices, meaning its manifold ways of applications and use, quickly grows in terms of practical endeavours [4–6], and considering the potential impact they may have on architectural competence, theoretical considerations may be drawn in order to further the understanding of architectural practice. By examining the intersections between data practices and architectural practices, the study recognises the reciprocal relationship between data production, its sources, and the actions required for its application. The exploration extends to the development of the intricate relationships

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among data, its conditions of existence, its devices and the production of related facts and technologies. As the architectural landscape embraces new tools capable of synthesising diverse datasets, this paper navigates the evolving significance of data and its stages of institutionalisation, offering critical insights for architects in shaping the trajectory of design action within data-rich environments.

The contribution will explore first the materials and methods and the empirical foundation, emphasizing the relationship between data-driven approaches and urban concerns. Second, the sociotechnical framework will be introduced as the background within which the architectural project is considered. Third, specific case studies will be examined in terms of methods, goals, and tools for data synthesis. Subsequently, the evolution of data-related facts and technology will be explored, addressing the consequences for architectural practices and design action in terms of critical and theoretical understandings.

2 Materials and Methods

The intricacies urban environments face making data a required asset for supporting decision-making processes: ensuring sustainability, improving performance and well-being, and adapting to evolving needs [2, 7]. This spectrum of challenges effectively intersects with the domain of architectural design, and, as such, there is an escalating research interest in this domain to uncover the multifaceted applications of data [8, 9]. The widespread research interest is exemplified by the active efforts of many laboratories and research centres. Examples of such laboratories will follow to illustrate the empirical ground over which considerations are later drawn, while providing a picture of the evolving landscape of research efforts, which scope of investigation lies with data practices and finding ways to use data towards urban applications.

The *Urban Ergonomics Lab* in Beijing is committed to devising innovative spatial strategies that tackle diverse issues in urban space and architectural practices impacting the sustainability of Chinese cities [10–12]. In the Netherlands, a cluster of laboratories working on similar issues are the *Amsterdam Metropolitan Solution*, the *Senseable Amsterdam Lab* and *The New Open* at TU Delft, which use Amsterdam and other Dutch cities as testbeds for data collection and synthesis [4, 13–18]. The research carried out by these laboratories is analysed to determine what concerns both the literature and their ongoing projects to highlight the actors taking part in the development of knowledge in data-driven architecture making.

The laboratories so far showcased represent the main case studies closely observed. However, many other examples exist around the world, encompassing very similar research interests. In Boston, the *MIT Senseable City Lab* in Boston is a well-known research centre committed to examining urban dynamics, and the *Civic Data Design Lab* shares similar interests focusing more on human-generated social data, with projects extending beyond the U.S. and oriented towards policymaking [19–22]. Affiliated with *MIT Senseable Lab*, the *Stockholm Senseable Lab*, and the *Singapore-MIT Alliance for Research and Technology*, provide other perspectives on data practices. In Italy, the Milan-based *Laboratorio di Simulazione Urbana Fausto Curti* engages in research projects to find a middle ground between human-generated and environment-generated data [23–26].

3 The Sociotechnical Reading of the Architectural Project

Data practices refer to those research efforts focused on tackling the vastity of data and conceptualising practical applications and theoretical issues. Regarding urban environments, the challenges are manifold, and data is increasingly considered a favourable resource. However, strategies concerning the development of urban environments intersect with architectural practices and the design process. It is necessary to consider design action to delve into the development of data practices and their meaning.

The architectural project can be understood as an inherently processual entity, not merely a result but a collection of practices that unfold over time. While the ultimate output is realising a physical modification of space, architects, in their daily endeavours, do not directly build walls. Instead, their operations and actions materialise in the form of the project itself—a dynamic and performative cloud of documents capable of effecting tangible changes in the world [27]. In breaking down the intricacies of architectural practices, it becomes evident that architects primarily engage in creating and exchanging documents. This perspective stems from the inherent needs of the design process, where any social or bureaucratic interaction must be made explicit and communicated to other actors [27]. For this to happen, the architect relies on specific supports, such as records, inscriptions, and documents whose codes are commonly known and shared among the actors involved [28].

The design process thus unfolds through the continuous exchange of documents among various interlocutors and actors. This cycle, driven by repetitive exchanges that open and close to possibilities, happens through the progressive expansion of this documental cloud, which increases in size and complexity over time. The multiplication of documents and their increasing concatenation play a pivotal role in propelling the project through many stages of institutionalisation [3]; if it works, this rhythm ends with a space modification. The project's first support for exchange is a variety of documents, from sketches to technical drawings, from emails to reports, and so on. This exchanging activity is a collaborative action involving at least two actors negotiating and producing further registrations. Observing such processes this way reveals a direct correlation between the growth of the documental cloud and the increasing number of actors involved. The reticular-relational model, as developed by Bruno Latour [3], aptly captures the multiplicity of documents exchanged and produced within this network, highlighting the transdisciplinary nature of the exchange essential for project development. When one looks at the practices of making architecture, through which space is modified, action is hybrid and diffused among actors, both human—architects, engineers, stakeholders, citizens—and nonhuman—objects, tools, technologies, norms, constrictions, organisations [29–33]. Within this intricate web, the succession of actions occurs thanks to and because of humans and nonhumans who symmetrically partake in the making [34]. We can imagine architects in the very first stages of a project being engaged in the process of considering instances and problems, exchanging ideas and solutions with other architects, reach a temporary stop, after which maybe other actors are brought in to allow the project to continue developing. Here, architects are human actors who explicitly express their considerations and exchange them with other human actors through nonhuman carriers: instruments, tools, and codes. Their presence is as much relevant and necessary as it is that of human actors [27, 34].

While understanding the core actions of architects is set on document exchange and production, their role takes place among a reticular network of actors where they develop strategies that are context-specific, never univocal, and dynamically adapted to the nuances of each context [27]. Design action unfolds within identifiable spaces akin to Latour's scientific laboratories, aptly termed "bottega" and "offices" [35]. These spaces are the container from which the documentary multiplicity emanates, encapsulating transdisciplinary competencies and serving as the professional domain of architects. Here, materials, tools, and technologies serve as instruments through which the project materialises into written works. In these environments, space is scrutinised, problems are analysed, information is synthesised, visions and narratives converge, and instruments and architects become intertwined.

4 Results

Architects have always been concerned with the ways of processing information within the design process. Today's great potential with data and its embedded information lies in the vastness of datasets derived from numerous sources, which could be examined comprehensively [36–38] to let new meaningful urban dynamics emerge.

Beyond present issues, the *Urban Ergonomics Lab* anticipates future challenges and aims to enhance the quality of urban spaces, challenging traditional design practices and the referentiality of architects as sole decision-makers. Indeed, the premise for the development of *Urban Ergonomics* is that the subjective perspective of the architect is recognized as problematic because it is neither universal nor reproducible. What is proposed with *Urban Ergonomics* is a design method where the use of data represent the asset to enlarge the scope of considerations the architect would otherwise be unable to reach. [1, 39]. To do so, studying the relationship between human behaviour and spatial design and finding possible bridges is crucial. The objective is to exploit social and behavioural dynamics data to design [1, 6]; this also implies prompting a reassessment of architectural practices by developing methods to support decision-making at the scale of architectural and urban design: this is done by integrating the knowledge developed on datasets reflecting people's interactions with the form of urban environments. To carry this objective forward, the laboratory has been implementing a methodology to become integrated into design processes, which allows the translation of collected data into viable information to support design decisions. To do so, an initial hierarchical taxonomy of experiences is deployed, and a set of tools is adopted to analyse and quantify them. The registering devices are thus essential to allow the collection of data that measure physiological responses to the environment.

The *Amsterdam Metropolitan Solution* aims to foster innovation and address urban challenges by establishing collaborations among government bodies, businesses, research institutions, and citizens. Here, solutions for sustainable urban development are implemented. Many of the research projects currently under progress are focused on harnessing data deriving from phones, social media, and urban sensors. With such assets, the aim is then to predict behaviour of people in indoor and outdoor spaces while also developing tools that allow the integration of different and heterogeneous datasets on the same platform [2, 14, 16, 19, 40, 41]. With a combination of ongoing projects each tackling different topics and issues, this laboratory, in collaboration with many other stakeholders, has been focused on leveraging social media data, open data sources, and environmental data to be supported and analyzed critically on the platform called "Social Glass" [2]. Its objective lies in generating valuable insights to enable a better-informed decision-making process to be used by third parties, from public entities to private firms working with urban environments, such as architects and planners.

While the *Urban Ergonomics Lab* is completely focused on developing a methodology of action while working on specific architectural projects, the *Amsterdam Metropolitan Solution* carries out research projects whose aim is to showcase issues and produce general solutions. Another element of difference is the nature of the data that is collected and analysed: in the first case study, the data considered traces human physiological responses to the environment where the sources are human beings directly, whereas the others consider data deriving from other indirect sources, such as apps, phones, and online activity.

Among these laboratories, many differences may occur in terms of the types of data considered, their sources and how to transform them into knowledge and methodologies apt for use; what remains similar is the presence of a great variety of nonhumans that partake in the process of developing such knowledge. Without registering devices such as headset simulators, phones, or cameras, for example, none of these laboratories could collect data on human dynamics, process them and then devise ways to synthetise them in a representative and useful way. These explorations raise broader questions encompassing both the entities involved and the knowledge production process around the use of data. Data practices can be followed in their complex development to understand the intricate relationships among data, its conditions, and the production of facts and technologies concerning it [42]. Contemporary actors in urban processes and future strategies must consider the instances derived from data practices' empirical work and their theoretical implications. Architects' expertise and role may shift because the potential of data lies in the related emergence of new tools capable of synthesising different datasets. To understand this shift, it is essential to reconsider the evolving significance associated with data and its increasing stages of institutionalisation [43]. Data collection methods vary, whether indirectly through third parties or directly through experiments with the help of specific devices in different scenarios. Indeed, once data is collected, the ways it is assembled and meaning is construed can shift significantly across locations and projects. This process entangles humans, registering devices, data, synthetical tools, experiments, and projects, one influencing the other in a continuous back-and-forth dynamic. Effectively managing this complexity and communicating it to the scientific community, as well as establishing methods for data assemblages and tools toward specific objectives is a challenging task undertaken by research centres like those mentioned.

Drawing on the notion of black boxing as conceptually developed by Latour [42], it can be argued that data practices are still in the process of their making, and in this process, the social and technical dimensions are still openly at work to converge on final products. The outcomes of such data practices, whether a platform of data assemblage or visual tool showing hidden patterns concerning human dynamics are not yet opaque; their inner mechanism and the choices behind it can be traced and made visible [34]. In this sense, following Latour's and Yaneva's work, these research centres working to achieve the construction of facts and technologies on data represent a significant ground for observation, providing examples of the multifaceted, social and technical nature of design action [44, 45]. Thus, we can consider how the development of facts is happening and draw some critical considerations as to what insights data practices can offer to urban and architectural ones. When exploited for its embedded information, data becomes linked with the meaning of the phenomena it depicts. This can encompass various aspects such as urban, human interactions, and physiological responses to precisely configured spaces [2, 46]—all studied to inform decision-making at the architectural and urban scale. With the amount of data that can be collected nowadays, the possibility opens to scrutinising human actions and interactions and synthesising them to a degree that facilitates the derivation of statistical considerations. The underlying implication would be that, via experiments and simulations, ongoing projects can be tested, and the morphological features of already-built spaces can be assessed.

The experimental production of facts and technologies aligns with the main features of technoscience—experiments, simulations, instruments, and laboratory environments [42]. In this context, one outcome could be to offer a positivist view of data, one where its meaning is deemed and understood as objective [1]. This would imply treating data not as a simple trace but as a faithful description, objective and natural, of the phenomena it traces, and, in this sense, statistics and laws can be defined upon it [47]. This pursuit of knowledge on data practices has many implications for future practitioners, especially in the technological dimension of the profession, where new tools can represent a challenge to design action [48, 49]. Digital tools able to synthesise large quantities of data are already present in architectural design and, as Carpo noted, have a way of proving effective in changing its practices, both in terms of technical development and conceptualising design problems [50]. However, as architects, when we question the efficacy of architectural action, is the issue genuinely rooted in a need for more objective, verifiable information?

Following the positivist vision that data can provide neutral and objective information, technological instruments, such as *location-based apps*, social media, and immersive realities [20, 51–53], enable the quantitative analysis of phenomena that could previously only be qualitatively studied [54]. The process involves leveraging statistics to legitimise this quantitative analysis. However, the neutrality of this process is apparent. Consider a scenario where multiple phenomena related to a space could positively support design decisions. In data collection, there is already a form of decision-making a priori that selects which phenomena and, consequently, which data are considered. This decision-making process is closely intertwined with the types of registering devices available to each laboratory in each context; it is thanks to these devices that the phenomena can be registered, and thus, data takes the form of an inscription [42]. Moreover, the selection, collection, and analysis are likely oriented towards a final, perhaps general, presupposed goal. In this context, data represents a phenomenon and enables it to be registered and interpreted. However, the entire process, from collection to analysis to synthesis, is not neutral; instead, it carries a complex social and technical network of interactions.

The approach of critical theory can help recognise the lack of neutrality in this intricate process, acknowledging phenomena on human dynamics and behaviour as socially produced rather than exclusively governed by natural laws [47]. The entire process, from collection to analysis and synthesis, is socially embedded, with each step influencing the others. Actors, including humans and nonhumans, continuously interact, shaping the data-rich environment. Devices used for data collection also play a role in influencing both data and human actors. This web of interactions forms significant chains, linking people, things, expertise, organisations, tools, devices, and instruments. In data-rich environments, these actors participate in a continuous process of bonding and rebonding, producing facts and technologies. Data itself takes on an instrumental presence and a capacity for action, thus becoming a powerful nonhuman actor in shaping architectural processes. Additionally, for data to manifest the phenomena it represents, various technical inscription devices are necessary to create these records [19]. Consequently, data functions as a nonhuman participant and can be interpreted as symbols, inscriptions, and documentation of the design procedure. Recognising the socially produced nature of these practices, architects must adapt to emerging tools and actively participate in shaping the trajectory of design action within data-rich environments.

Within this framework, the potential is for data to offer a unique opportunity to open the discourse to diverse and plural architectural perspectives. The vast datasets, derived from various sources that reflect urban dynamics, human interactions, and responses to spaces, present a rich tapestry of insights. As active participants in decision-making processes, architects could leverage these diverse perspectives to inform their designs and enrich the dialogue surrounding urban development. In embracing plural perspectives, architects can harness the power of data not only as a tool for technical advancement but as a catalyst for inclusive decision-making. The very nature of data, with its multitude of sources and narratives, encourages architects to consider a broader spectrum of influences in their design processes. This inclusivity fosters a more holistic and responsive approach to architectural practices, aligning with the evolving needs of diverse communities.

5 Discussion and Conclusions

This study's findings lie with the possibility of observing and drawing critical considerations from the innovations brought about by research laboratories working with data applications to architectural and urban environments. As the creation of novel approaches and instruments for maximizing the potential uses of data in urban settings is increasing, collected data can be translated into insightful knowledge to support design choices. However, in navigating the evolving landscape of data practices within architectural research, we find ourselves at a crucial intersection of technological innovation, design processes, and societal implications. Data integration to the project challenges traditional notions and reshapes the profession's technological dimension. Along with practical applications, this potential for translation and the impact on architectural competency should be addressed theoretically as well. Within the theory of the architectural project and the relational reticular model of distributed action, as developed by Latour, it is possible to recognise the lack of objectivity and neutrality that data seem to represent and thus comprehend it as yet another actor coming to play a part in the design process. In this sense, the potential impact of this study lies in observing and detailing the development of facts and technologies within these data-driven research which can lead to an analysis of this innovation, thus allowing architects to actively reflect on their role and competence in a network of actors. Within this perspective, decision support tools derived from data hold the potential to go beyond conventional boundaries and catalyse a shift towards more inclusive, equitable, and sustainable architectural practices. However, providing contextual descriptions of very specific research efforts in data practices limits the study to situated descriptions and theoretical considerations. Future prospects may be represented by undertaking detailed examinations to understand how such methodologies and platforms used in data-driven architectural practices might evolve into standard procedures. This may involve tracing the trajectory of their adoption, identifying key factors that contributed to their acceptance, and assessing the visible impact on architectural expertise.

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DECIDE: An Outcome-Driven Decision Support System for Urban-Regional Planning

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Abstract. This position paper argues that outcome-driven Decision Support Systems (DSS) are more appropriate than current data-driven approaches to integrate Multi-Domain Models (MDMs) in the context of sustainable urban-regional planning. This is because, for urban planning, DSS needs to provide fit-for-purpose answers to problems faced by practitioners when managing and designing city features. In fact, planners must cater for imagined scenarios, assessing viable solutions with regards to how they change in accordance with ever-changing constrains, to be able to improve cities towards becoming sustainable and resilient. The authors frame urban-regional planning as a design activity in which complex and interwoven requirements from multiple stakeholders need to be addressed by decisions involving multidomain knowledge. To this end, the paper highlights main characteristics of design activities, and then compares and contrasts data-driven strategies with outcome-driven strategies. This promotes the development of an outcome-driven DSS that better aligns with the needs of planners working with urban-regional development towards enhancing urban livability and addressing territorial inequalities. It then frames the role of data-driven strategies within outcome-driven DSS, showing how the DECIDE project embraces the creation of an outcome-driven DSS with punctual data-driven strategies.

Keywords: Decision Support Systems · Urban planning · Sustainable Cities · Digital twins

1 Introduction

The demands for efficient Decision Support Systems (DSS) based on Multi-domain Models (MDMs) and tailored for urban planning and analysis have attracted significant attention from both academic and stakeholder communities, given the increasing complexity involved on the prospects provided by smart-cities and their frameworks [1].

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Building-up those multi-domain systems have become important in the current, and to future-proof, urban planning as a discipline, since improving the efficiency of management and decision-making processes requires considering the many possible outcomes associated with urban phenomena.

However, due to limitations in computational processes and data retrieval methods, urban simulations and models tend to become restricted to closed Geographical information System (GIS) based environments, tailored to single aspects of analysis; or layering variables such as in the recent 15 min and X-minute city approaches [2]. When open, GIS-based environments have a more collaborative "information atlas" nature [3]. In both cases, conceived DSS tend to be non-modular, and have data-driven approaches where infrastructural, environmental, and socio-economic data coexist, but without establishing proper relations that are useful for decision-makers.

Networking databases and models into actual instruments to operational research continues to be, as mentioned in [4–6], the historical issue in developing DSS for urban planning. Moreover, upgrading these systems so that they become effective instruments to aid decision-making in urban planning, means they need to provide fit-for-purpose answers to problems faced by practitioners when managing and designing city features. Thus, an efficient DSS must cater for imagined scenarios of different types, and enable decision-makers to assess solutions for these scenarios with regards to how they change, to improve cities towards becoming sustainable and resilient.

Scenario simulation and experimenting with imaginary futures are core activities in design [7]. This relates to the idea of conceiving DSS for urban planning as design tools. DSS tools that enable scenarios can thus be assessed with regards to their suitability to the different requirements imposed by different urban stakeholders, set together with parameters of livability, environmental sustainability, and disaster risk reduction.

This proposition is far more challenging than simply using existing DSS set within GIS, such as multi-criteria evaluation and multi-objective evaluation systems [8]. It implies understanding the needs and aspirations of different stakeholders involved in urban planning to develop fit-for-purpose models, analysis processes, and courses of actions, to better meet their needs. It also implies understanding that the implementation of solutions at the urban scale is slow and tends to happen in constantly changing environments. This means that these scenarios need to accommodate for change and uncertainty in terms of the outcomes they are expected to bring, as well as the risks on not fulfilling the requirements they were originally supposed to achieve.

The first set of implications suggests framing urban-regional planning as a design activity, in which complex and interwoven requirements and constraints from multiple stakeholders need to be addressed by decisions involving multidomain knowledge. It highlights that DSS should be outcome-driven. The second set of implications suggests constant change cannot be ignored, meaning feedback loops between proposals, implementation, and management, need to be established to ensure solutions are fit-for-purpose, resilient and sustainable.

This paper proposes the fundamentals for an outcome-driven DSS for sustainable urban-regional planning based on the integration of models from multiple domains. The premise behind developing an outcome-driven DSS for urban-regional planning is understanding planning as mainly a design activity. The paper also frames the role of data-driven strategies within outcome-driven DSS, showing how the DECIDE project embraces the creation of an outcome-driven DSS with punctual data-driven strategies.

Section 2 defines what are the main characteristics of design activities that call for an outcome-driven approach to DSS. Section 3 then contrasts and discusses the main characteristics of data-driven strategies in relation to the main characteristics of outcome-driven strategies, arguing that urban planning DSS should be mainly outcome-driven. Section 4 explores the issue of assessing design solutions or suitability of outcomes to fulfill stakeholders needs in a constantly changing environment, promoting the role of data-driven strategies within an outcome-driven DSS. Finally, Sect. 5 introduces the DECIDE project and its research design, proposing it as an example of how to conceptualize an outcome-driven DSS with embedded data-driven strategies.

2 Main Characteristics of Design Activities

Design assumes a pivotal role in the planning and making of built-environments, as practitioners must formulate cohesive spatial configurations and programmes that encompass considerations such as land-use, transportation networks, agents' behaviours, plus economic and environmental sustainability [9]. In this regard, urban-regional planning aligns with the essence of design choices, where a parallel can be drawn between the intentional organisation and coordination of diverse elements within a specific geographical area, and the strategic decisions inherent to design. This underscores urban-regional planning as an inherently design-oriented activity.

In *The Principles of Design* Suh [10] highlights that the key characteristic of design activities is that they are driven by design requirements and constraints. Therefore, decisions undertaken throughout the design process need to transform what a situation is into what a situation needs to be to fulfill them. To this end, design decisions are mainly outcome-driven; they are fit-for-purpose to fulfil a set of prescribed outcomes.

However, to propose design solutions, designers must understand the needs of all stakeholders as well as the constraints on what can be achieved [10], and the problem to be addressed. Since design problems tend to be complex and involve multi-domain knowledge, designers tend to better understand the problem while trying to solve it [7, 11], evaluating how well proposed solutions suit the problem at hand. Solutions designed to fulfill requirements and constraints need to be considered with regards to how well they respond to these requirements and constraints, in an iterative, evidence-based, and testable way [10].

To this end, solving design problems combines strategies used to make decisions towards achieving desired solutions with strategies used to test the quality of the solutions implemented. Particularly, "decisions are balanced to achieve overarching project targets, negotiated among project team members, propagated into the information flow of the design process, and subsequently revised as the project develops" [12]. Therefore, design problems: (i) have briefs, with information related to requirements and constraints; and (ii) use multi-domain decision support methods and information management systems, as well as project control methods, to ensure desired outcomes are achieved in a satisfactory manner [13]. In a changing environment, these characteristics call for the potential use of data-driven strategies to be punctually implemented in a fit-for-purpose way throughout the design process towards controlling, testing, and feeding back solutions.

3 The Data-Driven Paradigm

In the past decade, data-driven strategies for decision-making became increasingly sought by both practitioners and researchers. This open pursuit for deeper problem understanding resulted in the creation of a myriad of 'predictive models' with questionable usefulness, and potentially issues related to biased samples, weak and flawed correlations, and pernicious feedback loops [14]. The data-driven approach can be interpreted as a close follow to economics' Game Theory, which proposed the alluring idea of searching for comprehensive information from widely available data to enable 'optimal' decisions to be made, towards fulfilling the most efficient business or policy outcome [15, 16]. This approach to decision-making adopts a rather *Marshallian* [17] paradigm, focused on an asymptote approach towards the optimal (considering all other things equal), which in the economic jargon is known as a *"point of equilibrium"* [18].

In urban analysis, such data-driven approaches have become the norm, especially after the development and popularization of smart cities [19] and, later, X-minute City [20] concepts, which require extensive datasets and right proxies to gauge how urban dynamics and city life occur. This approach can be seen as rather deterministic, reinforcing pre-existing beliefs and conditions with poor capacity to enable transformative change towards promoting new designs that ensure diversity and fairness [14]. Data-driven approaches can provide multiple outcomes. However, this does not mean that they are necessarily fit for purpose, as those are data-dependent (Table 1). This makes them suitable for grounded problem diagnosis and prediction, as they unfold patterns in events to define achievable outcomes based on available data. Still, since patterns are grounded on available data, they often provide knowledge, and recommendations that only work within the context of a specific problem [21]. This means that data-driven models are mostly not transferable, nor general. Therefore, they require domain expert knowledge to be validated and useful [22] and inform decision makers on achieving desirable outcomes.

Since data-driven models are not developed based on domain knowledge but by drawing patterns from available data, they depend on the data scientist to deploy sophisticated statistics, and potentially machine learning and AI algorithms, to extract knowledge and trends [21]. To this end, these models require large amounts of quantitative data and proxies to undertake predictions, and draw valid inferences on historical data (post-factum), displaying 'results' rather than concrete pathways to decision-making. What can lead to issues related to validity if proxies are not appropriately selected and if correlations are misinterpreted as cause [14]. In addition, since pattern recognition is grounded on data, data-driven strategies depend on the Internet of Things (IoT), secure data-sharing protocols, and storage, that heavily rely on data providers [23]. Nevertheless, one can see how seductive they are to decision-makers as they are prone to automation and 'variabilise' everything. Data-driven models reduce problems' complexity by transforming them into computable entities. At the same time they enable feedback loops to be established so that 'intelligent' models can learn with constantly increasing amounts of available data from the IoT, towards improving their efficiency [23].

In this sense, data-driven models are information-focused, often rich in data, but poor in providing insights and/or pathways as to how decisions can be made to reach desirable outcomes [21]. Outcome-driven strategies and models challenge some of the paradigms set by data-driven strategies and models.

4 From Data-Driven Towards an Outcome-Driven Decision Support Systems

In outcome-driven strategies, the main objective is to reach results that are fit-for-purpose, i.e. tailored to the expectations of the user/decision-maker. This aligns with overarching design objectives that cater for different needs of the multiple stakeholders involved in the design process, and constrains on what is possible to be achieved [9]. It comprises a shift in efforts – and in the course of actions – from data collection and organisation to pattern discovery in a dataset that *fits a purpose*, towards what the decisions are made for, with a specific result – a *fit-for-purpose* outcome based on precise data – in mind [21]. These are fundamental characteristics of design problems [9, 25], and the main rationale for arguing in favor of outcome-driven DSS in urban-regional planning.

As the focus of these strategies is to recognise how desired outcomes can be achieved considering the requirements and existing constrains, identifying what are the key decisions and indispensable datasets – or the core elements – required for the attaining expected outcomes becomes essential. Therefore, models supporting the decision processes have only the necessary information to answer specific questions and data collection activities focus on sufficiency rather than quantity [21]. Models are built with a purpose on what is expected to emerge from the data gathered towards achieving a pre-established set of satisficing conditions [25] or solutions. These models are rule-based (normally science-based), or based on domain-knowledge heuristics. They are used simultaneously or sequentially, making the process of achieving desired solutions a sequence of events and arguments, with analyses tailored to achieving specific outcomes, and analytical methods and models chosen based on their relevance to the reach these outcomes [26].

Domain experts are the ones identifying the necessary data to be used. They build and/or use knowledge models or heuristics to reason with data towards achieving a specific outcome discussed with the stakeholders. Additionally, they create their own repertoire of pairs of data-to-be-collected/model-heuristics-to-be-used, re-using them again and again, every-time a new problem emerges. Meaning that sequences of events are custom-based to the activity at hand, and events or arguments are transferable [11]. This enables quantitative and qualitative data to be used and sequences of events and arguments to be built in multiple ways, including the "capturing of human agency in change and development" [24].

Still, these characteristics are not as suitable for automation and the establishment of feedback loops. The role of uncertainty needs to be considered throughout the process as there is no feedback to enable adjustments to the solution after it is implemented. In limiting the data input to the essential, outcome-driven strategies must address uncertainty

Table 1. Comparison between data-driven and outcome-driven strategies [based on 14, 24, 26]

	Data-driven strategies	Outcome-driven strategies
Type of outcome	Data-dependent (multiple) outcomes	Fit-for-purpose satisficing outcomes
Focus/ Purpose	Problem diagnosis, analysis, prediction – identifying *what*?	Solution development and decision-making – identifying *how?*
Analysis Process	Feedback loops. Unfold patterns in events to define achievable outcomes	Rule-based and/or narrative-based. Use causal events and/or heuristics to meet desired outcomes
Units of analysis	Variables	Events/arguments
Type of analysis	Statistics, machine learning, AI require domain knowledge to be validated and useful	Causal models and/or heuristics. All domain-knowledge based
Type of data	Available data only	Meaningful and/or hypothetical data
Amount of data	Large amounts of data to draw valid inferences	Sufficient data to make decisions
Uncertainty	Based on training datasets, large datasets, curated datasets	Based on assumptions, risk assessment and uncertainty models
Scope	Mainly based on quantitative data accepts continuous change in variable attributes, uses feedback models, enables models to learn with the data and improves their efficiencies	Accepts quantitative & qualitative data and analysis processes, based on narrative/processes with dynamic models and sequence, ordering and context of events/arguments
Strengths	Incorporates feedback, moderates flow of inferences *"Captures continuous variations in development and change with powerful mathematical models"* [26]	*"Captures the role of human agency in change and development"* [26]
Weaknesses	Correlations used as causation, use of proxies to assess results, work based on historical data, often limited fairness	No feedback incorporated, linear flow of influence
Model developer	Data-scientist & data providers	Domain experts (in collaboration with stakeholders)

and complexity to a more refined degree. This calls for the use of sophisticated methods to deal with uncertainty as well as risk assessment methods, which go from probability and statistics up to agent-based models to gauge how well proposed solutions align with desired outcomes, and how well desired outcomes match the needs and aspirations of stakeholders as rationally assumed by decision-makers [26, 27]. Although outcome-driven strategies shift the paradigm towards a more guided approach to decision-making, and the construction of fit-for-purpose DSS, nothing prevents data-driven strategies from being used within outcome-driven sequences of action, as those can be powerful to support controlling and testing generated solutions.

5 Building and Outcome-Driven DSS: The DECIDE Project

The DECIDE project (Decoding Cities for Informed Decision Making) aims to develop and test a framework for an outcome-driven DSS, based on the integration of Multi-Domain Models (MDMs) for sustainable urban-regional planning. The DSS addresses territorial inequalities through the interpretation and prediction of movement dynamics according to different modes of mobility, accessibility levels to services and road-network resilience, to promote livability. It applies state-of-the-art configurational models and spatial frameworks for representing urban-regional dynamics, supporting strategic and operational decision-making.

Urban livability interprets multiple key-factors related to agents' movement (e.g. urban form, natural environments, road-network configuration, and personal habits or characteristics that influence preferential routes' choice), and associates those to territorial resilience (e.g. identifying the fragility points in road-network, plus urban-regional exposures, imbalances, and disparities). These aspects make the DSS core. The MDMs that link to the DSS will integrate functional aspects of urban-regional areas (e.g., economic activities, public activities, and the distribution of living areas) with environmental and built-environment aspects (e.g., improvement of circulation, CO_2 reduction via pedestrianization, cycling, and fleet electrification) forecasting their relations with movement network spatial configurations.

MDMs will be applied to interpret general hierarchical relations between urban-regional spaces (e.g., X-minute cities, spatial inequalities, city-systems linkages), and to inform planning for disaster risk reduction. A Digital Twin (DT) approach will be used to organize the MDMs into a DSS. This involves creating a virtual representation of the territory in a GIS environment that can be updated with near Real-Time Data to simulate scenarios when urban systems are subjected to temporary or permanent change. The DT will provide stakeholders and planners with immediate access to spatial knowledge of different urban phenomena including movement dynamics, road-networks' redundancy and fragility, environmental risks, and the potential outcomes of events/interventions. The outcome-driven DSS will enable decision-makers to design cohesive spaces and be more efficient and effective in their decision-making processes.

The DECIDE project comprises three working packages (Fig. 1). Its framework is mainly outcome-driven and developed through an iterative process with stakeholders. WP1 focuses on identifying MDMs outputs useful to decision-making together with case studies for testing the DSS. Useful outputs will be then categorised in terms of their complexity, and in accordance with the post-processing techniques needed for MDMs' data extraction (e.g. AHP, Optimization routines, Boolean operation overlays, etc.). Next, fit-for purpose post-processing techniques will be designed and implemented through Python scripts in GIS to produce useful MDMs outputs (WP1 and WP2). These scripts will be held in the project's Git-hub version-controlled library, to enable wider testing and dissemination to the academic community while still under development. A user manual and online tutorial to use the GIS scripts to streamline the extraction of, and produce, fit-for-purpose information for common applications of MDMs in decision-making will be developed for professional stakeholders. Finally, the framework for a WebGIS tool will be shared, together with a short online tutorial to facilitate the DSS' practical application and on-the-go data visualisation by all users.

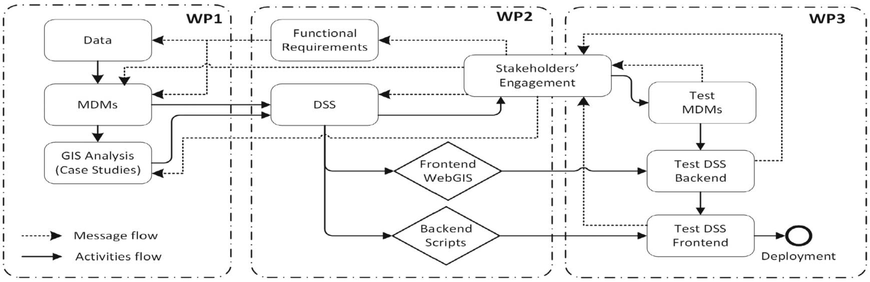

Fig. 1. The DECIDE project working package structure.

A period of iterative participative evaluation and testing of the DSS will follow. During this period, requirements and experiences regarding stakeholders' interactions with GIS tools, MDMs, and the outcome-driven DSS, will be collected and assessed. Critical feedback will be collected also about the established user-guidelines and the data retrieval scripts operation, as well as the DSS effectiveness in aiding stakeholders' decision-making.

The fact that urban-regional processes are highly dynamic, constantly changing over time, calls for data-driven components to be incorporated into the DSS, justifying the adoption of a Digital Twin (DT) approach. Inserted on a DT, the MDMs will empower urban planners to visualise natural movement patters together with environmental and economic aspects, and digitally assess the effects of possible modifications and/or interruptions to different mobility networks as part of scenario-based assessments. The improved performance that a real-time system provides will enable gains in the efficiency and transparency of decision-making processes, reduction of costs – both financial and time-related – to implement planning and policy actions, plus provide routing-related advice in the event of temporary or permanent urban-regional circulation systems' interruptions linked to extreme events. Although both stakeholders and academic communities have strong interests in such DT tools, this is often obscured by a lack of in-depth knowledge regarding network analysis and models that can assist understanding of critical resilience factors related to the functioning of road network systems.

6 Concluding Remarks

Data-driven strategies can be powerful in support controlling, testing, and feeding back solutions being generated, particularly after solutions' implementation and/or in constantly changing environments. However, we argue that outcome-driven strategies are imperative to handle the dynamic nature of urban-regional planning, as they incorporate design principles that are tailored to propose the required alternative/generative outcomes. In that aspect, adopting an outcome-oriented approach becomes important, as it allows to frame urban-regional planning as a design activity, in which complex and interwoven requirements and constraints from stakeholders can be properly addressed. Additionally, it offers more flexibility with respect to pure data-driven strategies. As we move forward with the DECIDE project, further endeavors will warrant to establish the operational framework for the proposed outcome-driven DSS, outlining the core principles that ascertain the broader applicability of this instrument in real decision-making contexts.

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How Can Participatory AI Implement Problem Structuring Methods for Urban Sustainability Enhancement?

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Abstract. Within the dynamic realm of urban development, SDGs underscore the pivotal role of citizens' engagement in nurturing inclusive and collaborative urban decision-making processes. This participatory ethos proves instrumental in comprehending the multifaceted impacts of choices, fostering co-design, and empowering communities. Participatory Artificial Intelligence (PAI) and Problem Structuring Methods (PSMs) emerge as a strategic approach to operationalize participatory practices within this context. This method article delves into the interconnected dynamics of PAI and PSMs, highlighting their potential to enhance collaborative problem-solving and propel urban sustainability. The research introduces a methodological framework that seamlessly integrates PSMs and PAI phases through the adoption of the Activity Theory and the Agile Methodology. This approach prioritizes a human-centric perspective, fosters collaboration and facilitates the achievement of common goals in a structured manner. By leveraging the capabilities of AI in data analytics, community engagement, and scenario planning within the context of PSMs, it is possible to navigate the intricate landscape of sustainability challenges with a holistic and well-informed approach. The present research intends to demonstrate how PAI and PSMs together form a synergistic approach able to define inclusive and sustainable urban strategies based on evolving urban contexts.

Keywords: Artificial intelligence · Participatory process · Problem structuring methods

1 Introduction

In the dynamic realm of urban development, achieving sustainability necessitates collaborative efforts among various stakeholders including governments, civil society, scientific communities, and businesses. Beyond conventional top-down methodologies, Sustainable Development Goals (SDGs) within the urban context advocate for the adoption of participatory approaches that incorporate diverse perspectives in decision-making processes [1]. At the core of this pursuit lies the recognition that inclusive decision-making processes are essential for comprehensive stakeholder engagement. This participatory

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ethos is pivotal for understanding the multifaceted impacts of decisions, establishing a well-informed framework for decision-making and enhancing its quality by providing access to expert and non-expert knowledge and a broader range of experiences and perspectives [2].

Navigating the complexities of this participatory perspective necessitates inclusive decision-making, where the concerns of all stakeholders are meticulously considered. It is within this framework that Problem Structuring Methods (PSMs) play a pivotal role. PSMs offer systematic approaches to problem-solving and decision-making, acting as a bridge integrating diverse perspectives and stakeholder interests.

Defined as participative and interactive methods focused on structuring problems rather than directly solving them, PSMs have emerged to fill gaps in addressing complex, ill-structured problems—often termed "wicked problems"—resistant to conventional solutions [3].

PSMs actively support public authorities during the preliminary analysis of political actions, aiding in decision problem structuring and the development of technical or organisational solutions [4]. PSMs not only provide methodologies for understanding and addressing complex problems by involving multiple perspectives but also contribute to the evaluation process [5]. These methods help structure and analyze data, facilitating evidence-based decision-making. Their role in transparent decision-making processes ensures that the implications of different policy choices are communicated effectively [6].

Nowadays, also Artificial Intelligence (AI) has taken a 'participatory turn' [7], recognizing that participation serves to involve broader segments of the public in the development and deployment of AI systems. The increased focus on participation arises from evolving perspectives on the role of AI in our societies, opening the way for a more inclusive, equitable, and trustworthy AI.

Participatory Artificial Intelligence (PAI) is an approach to artificial intelligence that emphasizes the active involvement of various stakeholders in the development, deployment, and decision-making processes of AI systems. It seeks to democratise AI by including non-experts, domain experts, affected communities, and others in shaping the technology's goals, behaviours, and impacts [8].

In this method article, PAI is conceptualized as a facilitator of a collaborative approach to decision-making, wherein decisions are grounded in the collective insights and experiences of stakeholders. To enhance urban sustainability, integrating PAI with PSMs can offer a robust framework for addressing complex challenges. The contribution explores possible links between PAI and PSMs, highlighting the shared goal of involving people in decision-making. It examines how they can be interconnected to enhance the effectiveness of collaborative problem-solving.

The paper proceeds as follows: Sect. 2 clarifies the design methodology; Sect. 3 presents the literature survey results and the methodological proposal; finally, Sect. 4 expands on results through discussions and conclusions about the explored topics.

2 Materials and Methods

According to the research purpose of comparing PAI with PSMs, the design methodology was structured as shown in Fig. 1:

– Declaring the research purpose
– Setting research boundaries
– Identifying theoretical approaches
– Designing a methodological proposal
– Identifying future trends of the research

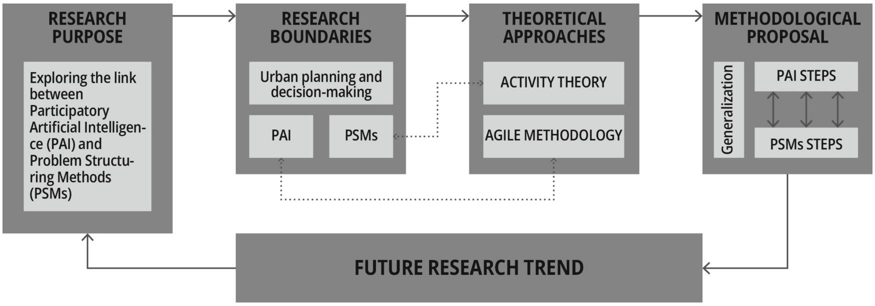

Fig. 1. Design methodology workflow

The research was addressed to explore interconnections between PSMs-based and PAI-based methodologies, methods, and applications.

Furthermore, the authors decided to set the boundaries of this exploration to the field of urban planning and decision-making, starting from more recent review articles on these topics. Whilst PSMs have been deeply explored in the literature since the 1970s, the research topic related to PAI is relatively recent, making it challenging to conduct a comprehensive analysis or find articles directly related to it. As a result, there is limited existing research in this area due to its novelty. However, this presents an exciting opportunity to contribute to the field by exploring new perspectives and insights in this emerging domain.

On the other side, a growing body of work has elucidated the various roles and formats that participation can assume in AI development. In particular, the literature review by [9] was selected as a starting point to explore the role of AI in stakeholder engagement and smart cities, identifying 62 papers categorized into 10 main clusters. Notably, one of these clusters specifically focuses on urban planning, encompassing a total of 5 articles, which the authors have selected since they deal with urban case studies.

Furthermore, the literature review on emerging PSMs by [10] was selected, by focussing on 12 publications showing applications to decision-making in the social field. Among these, 5 articles related to urban planning and regeneration processes at the city scale were chosen.

The output of the literature exploration was addressed to find relevant theories, methodologies, and similar and generalisable procedure steps to configure a methodological proposal based on PAI and PSMs integration.

Activity Theory (AT) [11, 12] and Agile Methodology (AM) [13] were explored to pursue these aims, emphasizing a human-centric approach, fostering collaboration, and achieving common goals in a structured way. In particular, AT was selected as the more recurring operational theory implemented into the PSMs. Concerning PAI—due to a lack of consensus on methods interpretation—the authors have chosen to explore the AM as a value-driven structured methodological process which has been implemented in collaborative contexts for software development.

Finally, the identification of recent research trends has made it possible to revise or adjust the research question by finding new topics.

3 PAI and PSMs Within Theoretical Frameworks of Activity Theory and Agile Methodology

The PSMs presented in the review article by [10] employ diverse approaches for addressing unstructured problems in urban planning and decision-making practice. The authors explore several methodologies based on community engagement models and innovative problem-solving approaches, e.g. the strategic choice approach [14, 15] and Activity Theory (AT) [11, 12], also integrating Multi-Criteria Decision Analysis and data visualization [16–19]. Each approach contributes unique perspectives and tools for structuring—more than solving—problems in the urban context. White [20] argues that OR interventions, exemplified by PSMs qualitative models, are complex events that require an alternative understanding, including multidimensional shared values [21–23] and intersubjectivity to support decision-making processes [24–26]. The collective behaviour was identified to evaluate these interventions, emphasizing the importance of analysing PSMs activity systems.

In particular, Capolongo et al. [27] propose a multi-criteria evaluation framework for urban regeneration processes, structured into three phases: intelligence, design, and decision. The authors emphasize the importance of considering multi-dimensional characteristics in the evaluation, involving the case study of an alternative building reuse for healthcare facilities. Konsti-Laakso and Rantala [28] developed a process model for managing community engagement in urban planning, integrating community OR theory, facilitative modeling, PSMs, and innovation management. Lopes et al. [29] present an innovative approach utilizing Soft Systems Methodology (SSM) and Theory of Inventive Problem Solving (TRIZ) to understand stakeholder concerns and identify solutions for conflicting goals. The researchers simulate stakeholder engagement in a metropolitan rail project, demonstrating the feasibility of this approach. Picchianti [30] explores a strategic choice approach in urban planning, focusing on coherence between strategic choices and operational plans. The research aims to demonstrate that a plan derived from strategic choices, with traceability in the decision-making process, proves useful for plan updates. Todella et al. [31] study the use of spatial configuration analysis (SCA) in building transformation at the district level, by focusing on a continuous process of conflicts and negotiations through social interactions with concern about physical forms and spaces.

The above-mentioned PSMs share issues related to stakeholders' engagement modality, conflict management, and mutual learning in decision-making. Indeed, the shown soft-OR interventions have been addressed to boost public participation through structured or semi-structured engagement procedures within the AT framework [14, 15].

AT explores the dynamic interplay between individuals and their social surroundings, emphasizing the role of activities in shaping human experience and behaviour. According to AT, a difference between activity, action, and operation has to be determined to manage conflicts in decision-making and to reach collaborative outcomes. Whilst an activity can be defined as a mediating artefact enabling the automation of a new routine or the construction of a new instrument, an action relates to a change in the real world or manipulation of reality. The operation, at least, is something that automates routine referring to optimization [32].

Within the intricate landscape of participatory design approaches, AM plays a crucial role [13], encompassing four key phases: requirements elicitation, identifying user values, biases, and lived experiences; design and development, involving participatory design with stakeholders, specifying aims and expected outcomes; testing, incorporating user feedback for the next iteration; and deployment, ensuring the developed AI system meets collective requirements [33].

Given the recent nature of the research field concerning PAI, it is frequently misunderstood or overlooked, sometimes merely seen as the intersection between AI and stakeholder engagement. This generates a gap related to the suitability of using different PAI tools and systems based on specific requirements of each project. In this perspective, AM allows the collaborative process to be supported in a structured and iterative way by guiding stakeholders towards a technology development linked to the elicitation of their needs.

In particular, Lieven et al. [34] developed an open-source co-creating platform for urban planning that combines online citizen feedback collection with city-scale devices and GIS. Seifert et al. [35] introduced a versatile software framework utilizing augmented reality for strategy development, evaluation, and visual preparation in urban planning and decision-making processes. Aguilar-Castro et al. [36] presented a city simulator game for Smart Cities, promoting collective decision-making, e-participation, and e-decision-making. Costa et al. [37] emphasized the potential of artificial intelligence, cognitive computing, and IoT in citizen engagement for smart city development, citing Guimarães engaged city initiatives as a case study. Taha [38] developed an application to facilitate information exchange, feedback, and user ratings, integrating micro polls exploring the potential of mobile social networking and geo-coding in city promotion and decision support for planners.

Aligning with the AM life cycle, the preceding articles accentuate stakeholder engagement in specific phases of PAI, particularly concerning data collection (requirements elicitation), data visualization (design and testing), e-participation (development), and scenario development (deployment).

4 Integrating PAI and PSMs: A Methodological Proposal

The methodological proposal—shown in Fig. 2—is an attempt to connect procedures related to PAI-based and PSMs-based methodologies, which are both grounded in the AT revolving around the interplay among material action, cognition, and societal dynamics in decision-making [11]. AT delves into the intricate connections between thoughts, behaviours, individual actions, and collective practices. Consequently, AT is grounded in practical application, emphasizing the influence of practices in shaping and enabling the processes of activity. Practices not only constrain and facilitate activities but also impact how recognition of action is granted and the types of relationships formed in an activity context. AT, encompassing activity systems, active participation, and the resolution of contradictions and dilemmas, provides a foundational framework for understanding urban development dynamics.

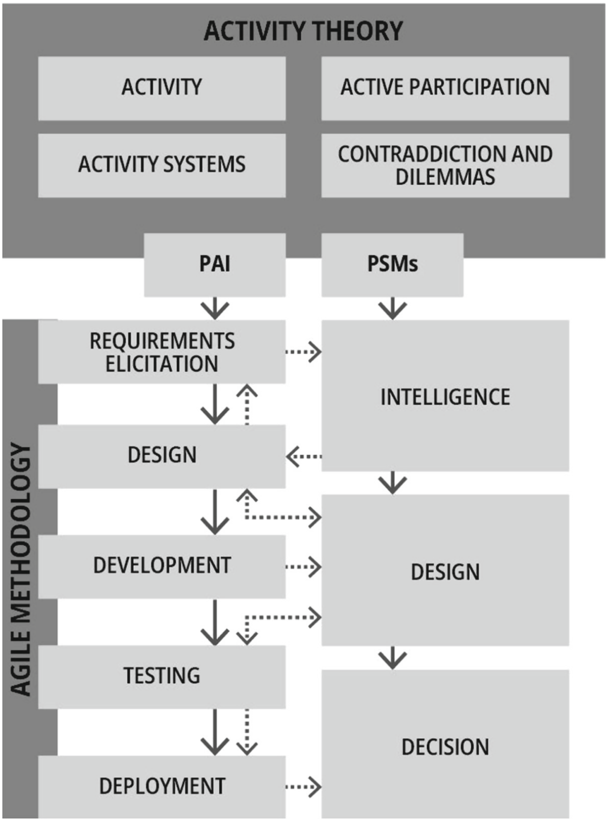

Fig. 2. Methodological proposal

Within this framework, PSMs are generally structured into three phases—Intelligence, Design, and Decision—aligning with AT's emphasis on analyzing and resolving activity system intricacies. Concurrently, AM facilitates the iterative integration of PAI, encompassing requirements elicitation, design and development, testing, and deployment. Agile, as a value-driven theory, is underscored by the four value statements articulated in the Agile Manifesto [39]. Agile methodology embraces human values such as trust, respect, collaboration, community, and delegation of authority. This iterative process ensures adaptability and responsiveness to evolving urban contexts.

The proposed methodological framework aims to synergize the strengths of PAI and PSMs, providing a structured and adaptive approach to urban decision-making that promotes inclusivity and sustainability. Nevertheless, connections and overlaps can be detected, especially in the context of developing AI systems for decision-making.

The methodological proposal aimed to compare PAI-based and PSMs-based procedural steps, as follows:

Requirements Elicitation (PAI step) and Intelligence (PSMs step).
In PAI, requirements elicitation involves understanding the needs, preferences, and concerns of stakeholders. In PSMs, the intelligence phase involves understanding the problem, its context, and the information needed for decision-making. The intelligence phase in PSMs can benefit from the insights gathered during requirements elicitation in PAI, enabling stakeholders to contribute qualitative information to boost the understanding of the problem context.

Design (PAI and PSMs steps).
PAI design involves the algorithms architecture and user interface based on stakeholder requirements. In PSMs, the design phase includes identifying key variables and modelling techniques for the decision problem, e.g. multi-criteria aggregation procedures and methods, spatial modelling in GIS, or weights elicitation methods. The design phases in both approaches involve structuring information. The design decisions in PAI inform the structuring of the problem in PSMs, ensuring that the identified conflicting needs are addressed in a pluralistic way.

Development (PAI step) and Design (PSMs step)
PAI development involves coding, training, and implementing the AI system. In PSMs, the design phase involves using structured information to identify potential solutions and develop models. The outputs of the development phase in PAI provide the context-aware tools and systems needed for designing the decision process in PSMs.

Testing (PAI step) and Design (PSMs step).
PAI testing involves assessing the performance and functionality of the developed system. PAI may involve iteration, revisiting earlier phases based on feedback, and improving the system or decision models. Feedback from testing in PAI can inform iterations in PSMs, enhancing the decision-making process, e.g. revising the model, checking the consistency of variables, and performing sensitivity analysis.

Deployment (PAI step) and Decision (PSMs step).
PAI deployment involves implementing the developed system in a real-world setting. In PSMs, the decision involves choice among alternatives or generating new alternatives by using the decision model in practice. The successful deployment of PAI ensures that the AI system is available for use in a collaborative decision-making process facilitated by PSMs.

5 Discussions and Future Research Trend

The overarching aim was to harness the capabilities of AI to promote citizen participation as a key element of the smart development of our cities, thereby defining a novel dimension of social engagement. PAI harnesses advanced algorithms and data analytics to engage a diverse array of stakeholders, ranging from citizens to local businesses and community organizations.

As PAI algorithms contribute to decision support systems, stakeholders gain access to a dynamic understanding of urban sustainability, allowing for the exploration of various scenarios and their potential impacts.

The integration of PAI-generated scenarios into PSMs enhances the problem-structuring processes, aiding stakeholders in visualizing potential outcomes and making informed decisions. Furthermore, PAI serves as a conduit for community feedback and involvement, capturing sentiments, preferences, and concerns related to sustainability initiatives. This wealth of qualitative data becomes integral to the participatory approach embedded within PSMs. Through this synthesis, stakeholders actively contribute to the problem identification, ensuring that diverse perspectives are considered. In addition, AI-powered visualization tools enhance communication by simplifying complex data and scenarios. As AI-generated visualizations become part of the communication strategy within PSM initiatives, stakeholders can more easily comprehend problem structures and proposed solutions.

The adaptive nature of PAI systems, continually monitoring and responding to changing urban conditions, aligns seamlessly with the adaptability inherent in PSM frameworks. Together, they can gain a synergistic approach that facilitates real-time adjustments to problem structuring based on evolving urban contexts.

Moreover, as PAI becomes an integral part of decision-making, there is a need for capacity building among stakeholders. This involves educating them on how to understand and leverage AI tools for data-driven decision-making. Integrating AI education into PSM initiatives ensures that stakeholders possess the necessary skills to engage with AI-generated insights effectively.

In conclusion, while PAI and PSM could have their distinct steps and objectives, they can complement each other, creating a more holistic approach to developing AI systems for decision-making that are not only technically sound but also responsive to the needs and insights of stakeholders.

Authors Contributions. The authors jointly conceived and developed the approach and decided on the overall objective and structure of the paper: Conceptualization, S.S.; Methodology, S.S. and G.P.; Formal Analysis, G.P.; Investigation, S.S.; Resources, S.S. and G.P.; Writing-Original Draft Preparation, S.S.; Writing-Review and Editing, S.S. and G.P.; Visualization, G.P.; Supervision, G.P. All authors have read and agreed to the published version of the manuscript.

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Polarisation vs Homogeneity: Unveiling the Heterogeneity of Evaluations for Urban Regeneration

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Abstract. Urban regeneration initiatives require a deep understanding of urban challenges, including both physical and social dimensions. Previous research often relies on aggregate analyses of the studied sample, summarising the population's evaluations into average values. However, this approach risks overlooking the social segments within a community and averages out any polarisation of assessments. This research proposes a preliminary cluster analysis approach to investigate the nature of values and challenges the limitations of previous studies. The methodology aims to first identify latent subgroups within the sampled population and then characterize their evaluations. The investigation is guided by two hypotheses: the first predicts convergence of evaluations by segments of the population, while the second predicts divergent opinions. In this case, it is important to consider the synthesis carefully, because the average synthesis reports only one orientation. The study stress-tests the methodology. It takes into account the data set previously studied by Micelli and Giliberto (2023) on the Piave neighbourhood.

Keywords: Sample heterogeneity · Opinion Polarisation · Cluster Analysis · Urban Assessment · Urban Regeneration

1 Introduction

The concept of "urban regeneration" refers to a complete development process that encompasses not only physical change-oriented renewal activity but also economic and social factors [1–4]. This perspective is based on the understanding of the urban phenomenon as a complex interplay of spatial and socio-economic factors [5–8].

The identification of the challenges faced by a city, or its parts, is a prerequisite for the development of policies and actions aimed at urban regeneration. A clear and concise understanding of the issues at stake should form the framework for the priorities. It is therefore necessary to identify whether the problems are due to deficiencies in physical resources, or to social aspects, or to the problematic nature of the interaction between the two components involved [9–11].

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A photograph of the values at stake can be taken by identifying both the evident aspects and latent factors that describe the material and immaterial components of an urban area [2, 3, 7, 12, 13]. There is a significant amount of literature proposing conceptual frameworks for both tangible and intangible aspects. These frameworks include the concept of walkability, which helps to understand tangible heritage [14–23], and social capital, well-being, and quality of life [24–31], which can be used to investigate the objective [32] and subjective [31, 32] conditions of individuals within specific local contexts. Some studies have been able to provide an integrated reading of these aspects by formulating an assessment methodology that allows for the simultaneous consideration of tangible and intangible aspects that define the qualities of a part of a city [11, 33].

However, it is important to recognise that these studies, based on semi-structured questionnaires, may not always provide accurate results. This is because they analyse the average values of the sample's evaluations in an aggregate manner, without considering any internal polarisations that the complexity of the issue might generate. Additionally, it is crucial to recognise that an individual's perception and evaluation of their state in a given context can vary depending on their experience and personal condition [36].

The question at the heart of this study, therefore, concerns the nature of the values measured. Are they the outcome of averages that compose the incomposable? Or are we dealing with general trends that can be acted upon without fear of conflicts or caesuras? The study aims to identify potential internal polarisations in the sample evaluations, which are typically considered in an aggregated manner.

To conduct thorough research, it is essential to supplement existing methods with a preliminary cluster analysis. This step identifies potential groups within the statistical sample, whose preferences and evaluations will be verified in a subsequent stage (see Fig. 1).

The research operationally examines a previously conducted study and stress tests the dataset to determine if the evaluations are consistent with the social articulation of the sample of participants. The dataset concerns the Piave neighbourhood in Mestre-Venice, disposed by Micelli and Giliberto [11]. Firstly, the research examines the existence of subgroups in the population sample through clustering. Secondly, the study examines the presence of emerging polarities in the assessments of specific social groups with particular needs.

Figure 1 displays the two hypotheses that require testing. On the one hand, the clusters have similar assessments and therefore, even if they are articulated, society is converging on the same direction. On the other hand, the clusters have divergent opinions. In this case, therefore, the synthesis must be considered with caution because we are dealing with opposing clusters and the average synthesis reports only one orientation.

2 Data

For several years, the urban context of the Piave district in Mestre-Venice has faced public safety and social issues [37–41], making it susceptible to further social speculation.

The sample consists of 169 people, 101 female and 68 male. The average age is 50 years, with a range from 11 to 88 years. The majority of respondents are Italian

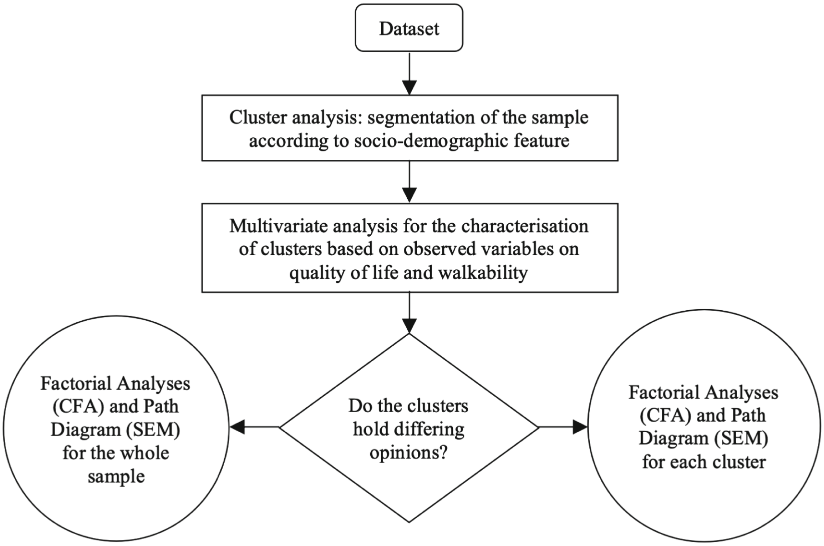

Fig. 1. Methodology flowchart

(97.6%). Looking at the resident population of the neighbourhood, only 62% are of Italian nationality. This means that the data collected only represents a portion of the population, not the entire population. Additionally, 65.1% of those interviewed identified as Catholic.

The education level of the respondents is remarkable. Over half of them, 53.8%, hold a university degree or equivalent, which is significantly higher than the regional average of 9.92%. Additionally, 35.5% of the sample have a high school diploma, which is consistent with regional statistics. Only a small percentage, 10.7%, have a lower level of education. It is worth noting that in the Veneto region almost 60% of the population has this level of education. The differences can be attributed to two factors. Firstly, the higher level of education among urban populations. Secondly, a possible self-selection process whereby the better-educated individuals present themselves on the public scene and participate in the questionnaire.

In terms of travel preferences, 72.8% of respondents walk or cycle, compared to 20.7% who use their own motorised means of transport.

Table 1 presents the descriptive statistics for the sociographic characteristics relevant to a detailed methodological analysis.

Respondents then rated quality of life and walkability using seven-point Likert scales ranging from 1 (negative) to 7 (positive), with a midpoint of 4 (neutral) to allow for variability in subsequent models [42]. Table 2 shows the variables examined using the semi-structured questionnaire.

Table 1. Descriptive analysis of socio-demographic characteristics.

Observed variable	Type of variable	N	Min	Max	Mean	sd
Years of residency	Scale	169	1	84	26.96	19.924
Age	Scale	169	11	88	49.57	17.493
Gender	Dummy (0: Female; 1: Male)	169	0	1	0.40	0.492
Lifestyle (total walking time)	Dummy (0: < 30'; 1: > 30')	169	0	1	0.78	0.415
Cohabitants	Scale	169	1	12	3.07	1.423
Income	Ordinal (based on ISEE indicator)	162	1	9	4.10	2.366
Education	Ordinal (1: lower level; 2: high school diploma; 3: university degree or equivalent)	169	1	3	2.43	0.679
Work	Dummy (0: No; 1: Yes)	169	0	1	0.67	0.470
Sport	Dummy (0: No; 1: Yes)	169	0	1	0.44	0.498
Preferred modes of travel	Ordinal (1: Walk; 2: Bicycle; 3: Public transportation; 4: Own means of transport)	169	1	4	1.93	1.203

3 Analysis and Results

To investigate the existence of subgroups in the population sample, the research proposes a clustering based on identified sociographic characteristics. In a second step, the study examines whether the identified social subgroups are associated with a different assessment of quality of life and walkability, and therefore whether the signal of dissatisfaction emanates from groups with special needs.

Cluster analysis, developed using IBM's SPSS software (Statistical Package for Social Science), aims to group observations according to sociodemographic characteristics (see Table 1) and to create clusters that are as homogeneous within themselves and as heterogeneous to each other as possible.

The steps for clustering include an initial preparation of the dataset and the measurement of the distance between statistical units for quantitative variables and the similarity for qualitative variables (which are in any case transformed into numerical values in the dataset). At this point, an exclusion clustering algorithm is applied to analyse the collected data and determine the distribution of the observations according to a non-ubiquitous principle. The method used is a non-hierarchical clustering with a k-means algorithm, which standardises the values to make them comparable.

Table 2. Factors and observed variables for quality of life (Q) and walkability (W).

Factors	Observed variable
Health	Q1: Physical health
	Q2: Mental health
	Q3: Lifestyle and degree of physical activity
Work	Q4: Job satisfaction
	Q5: Work flexibility
	Q6: Appreciation of the work environment
	Q7: Work-life balance
	Q8: Work productivity
Family	Q9: Time spent with the family
	Q10: Activities carried out together with family members
	Q11: Relationship with family members linked to the care dimension
Community	Q12: Social relations of the neighbours
	Q13: Differentiation of the neighbours by age and ethnicity
	Q14: Involvement in community activities
Neighbourhood	Q15: Overall appreciation of the neighbourhood
	Q16: Social context and relationships
	Q17: Attachment to place
Spatial perception	W1: Perception of safety in the space
	W2: Comfort linked to the functionality of the space
	W3: Appreciation of the experience linked to active mobility
Accessibility	W4: Pedestrian accessibility to community places
	W5: Pedestrian accessibility to places of leisure
	W6: Pedestrian accessibility to essential services
	W7: Pedestrian accessibility to complementary services
	W8: Pedestrian accessibility to the hospital and healthcare facilities
	W9: Pedestrian accessibility to schools and educational institutions
	W10: Pedestrian accessibility to the workplace
	W11: Pedestrian accessibility to places for sports activities

The hypothetical choice of a maximum of two clusters is based on empirical decisions. In particular, increasing the number of clusters reduces the reliability of the model, which generates clusters with an insufficient number of cases.

An analysis of variance (ANOVA) is then carried out to test the differences between the sample means, taking into account their respective variances. In defining the clusters, those variance profiles whose p-value was less than 5% were considered statistically significant and therefore decisive. The level of significance is shown in Fig. 2. Specifically, (**) p-value < 0.001, (*) p-value < 0.05.

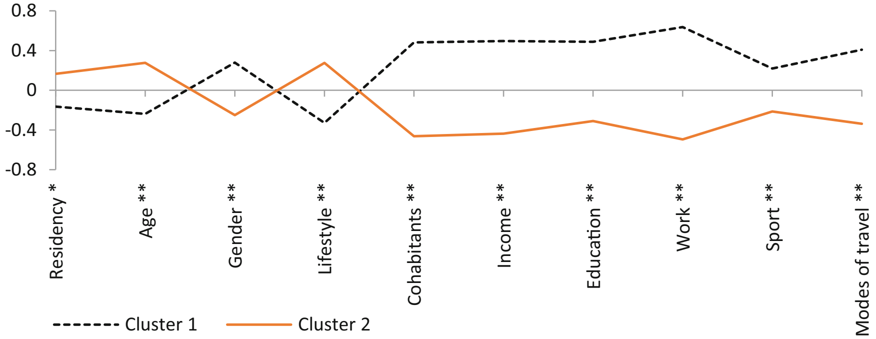

Fig. 2. Sample clustering.

Clustering produces two distinct groups with comparable numbers of cases, the first 76 and the second 86. From the total sample, 7 cases are missing because of the listwise exclusion mode.

The first group consists of mostly male cases under the age of 50. They are employees with above-average income and education. On average, the subjects participate in sports, but their daily commute is mostly by their own motorised means, presumably by car. They walk less than 30 min a day.

The second cluster consists of predominantly female cases with an above-average age, a lower average income and a lower level of education than the first cluster. They mainly walk or cycle and spend at least 30 min a day walking, but do not participate in sports.

At this point, it is possible to perform a multivariate analysis to characterise the clusters identified based on their assessment of the quality of their condition and their perception of the context in which they live.

To verify if the samples being compared originate from a population with the same variance, the study uses the Levene's test. As each sampling has little variations, in this instance, variance discrepancies are only likely to arise by chance. There is a significant difference between the variances if the Levene's test p-value is less than 0.05 (*).

Figure 3 illustrates the assessment of quality of life (Q) and walkability (W), highlighting the significant variables that satisfy the homogeneity test. In detail, the average of the ratings expressed by the sample as a whole and by the individual clusters is shown for each of the variables considered (17 Q variables and 11 W variables). The evaluations of the two clusters are significant in terms of appreciation of the work environment (D6) and feeling proactive (D8). They are also significant in their assessment of the family environment, specifically regarding the time spent with the family (Q9) and the activities carried out with family members (Q10). The two clusters have significant opinions on the perception of social differentiation of the neighbourhood (D13) and on the overall appreciation of the neighbourhood (D15).

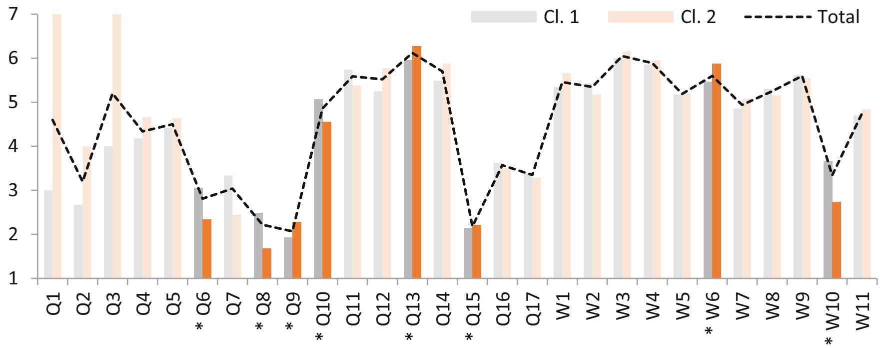

Fig. 3. Cluster characterisation. Assessment of the quality of life (Q) and walkability (W) variables for each cluster.

In terms of walkability assessments, the variables relating to the accessibility of basic services (W6) and workplaces (W10) are significant.

4 Discussion and Conclusion

Based on the results obtained, we can now examine whether the subgroups' assessments converge or diverge in relation to the overall assessments of the sample.

Figure 3 illustrates the evaluations, which demonstrate a significant convergence of evaluations between subgroups for the highlighted variables, with minimal imbalances in the characterisation of the clusters.

In particular, the scores for the family environment stand out. The first cluster spends less time at home on average, but engages in more family activities than the second cluster.

The work environment also deserves attention. The evaluations of the first cluster are positively unbalanced compared to the overall average. This is evident in the appreciation of the working environment, perception of one's own productivity, and accessibility of the workplace. The second cluster records ratings below the overall average.

Regarding accessibility, the study also reports varying values for the place of essential services. The second cluster expresses higher quantitative assessments than the first cluster.

The assessment of the context in which the people live concerns the differentiation of the social environment and the overall appreciation of the neighbourhood. The second cluster expresses evaluations above the average of the total sample in both cases, while the first cluster records lower values.

The results demonstrate the significance of the adopted methodology. It is useful for identifying social subgroups within the sample of respondents and investigating internal polarisations within an aggregate assessment. This enables the capture of specific needs of certain population groups or attributing possible problems to them.

In this case, the identified subgroups hold similar opinions, with only slight imbalances. Therefore, although society is duly articulated, it is converging in the same direction. Different characterisations of the sample could have resulted in different clusters, potentially leading to variations in assessments of the observed variables.

The methodology proposed here is preliminary when compared to the assessment methods in the literature, which suggest the collection of evident aspects, measured variables, and latent factors representative of the tangible and intangible aspects of urban contexts. In this case study, Micelli and Giliberto's conclusions are reinforced by the necessary segmentation of the surveyed population and the characterization of the identified clusters, which appear to converge.

The research results validate the proposed methodological flowchart, supporting the development of a methodological framework. However, further research is necessary for verification. This experimental method requires additional implementation tests. Future research may reveal divergent opinions among subgroups of the analysed sample. In such cases, it is important to weigh the average value of opinions or consider the polarities of the identified clusters to provide accurate results. It is important to recognise the complexity of the issue when analysing the value at stake.

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Thermal Insulation Material for Building Envelope: An Affordability Evaluation

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Abstract. Energy efficiency and greenhouse gas reduction have become two of the most important issues to address in fighting climate change.

According to UN data, the construction sector consumes more than 40 per cent of the world's raw materials and 13 per cent of drinking water. 39 per cent of global CO2 emissions come from the built environment and specifically from buildings.

In Italy, a similar percentage trend is confirmed (Ministry of Economic Development, The National Energy Situation). Overall, more natural resources are consumed each year than the planet is able to regenerate, making the need for a transition to a sustainable development model ever more urgent.

Based on the data, building stock and results provided by a recent study carried out by Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), the aim of this research is to evaluate of the economic sustainability of the most used insulation material for the thermal coating of building envelopes (such us EPS, Stone Wall and Glass Wall) by calculating the economic payback time.

Keywords: Economic analysis · Payback time · Thermal Insulation Material

1 Introduction

Sudden population growth, demand for new housing and infrastructure, rampant urbanisation and land consumption have made the construction sector the one with the greatest environmental impact.

According to UN data [1], the construction sector consumes more than 40 per cent of the world's raw materials and 13 per cent of drinking water. 39 per cent of global CO2 emissions come from the built environment and specifically from buildings.

In Italy, a similar percentage trend is confirmed (Ministry of Economic Development, The National Energy Situation). Overall, more natural resources are consumed each year than the planet is able to regenerate, making the need for a transition to a sustainable development model ever more urgent.

To achieve this, without falling into recession, it is essential to strike a balance between the three components of sustainability.

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In other words, it is necessary to convert the most widespread production model, the linear economy, to a circular economy based on reduction, recycling and reuse.

A production paradigm, applicable to the industrial, construction or energy sectors, that is characterised by an approach to the environment that is not merely speculative and consumerist, but which is able to work synergistically with nature.

In pursuit of these objectives, institutional policies must balance the need to preserve and conserve natural resources while ensuring the security, health and well-being of individuals and promoting investment, research, innovation and employment.

Since the greatest environmental impact is associated with the operational phase of buildings, due to energy consumption for air conditioning (heating and cooling), efficient and sustainable technologies is certainly the main, widely recognised strategy to reduce the energy demand [1].

As a result, multiple energy strategies have been implemented in Europe to improve energy efficiency and achieve significant energy savings, increasing total investments in the building sector by more than 10 per cent in 2020 alone [2].

The importance of achieving energy efficiency and savings in the building sector has also been emphasised by the International Energy Agency (IEA), which has provided useful recommendations to be taken into account in the building renovation process [3].

According to the IEA, zero emissions, energy efficiency and cost optimisation should be targeted when renovating. Furthermore, emphasising the importance of focusing on the renovation of buildings that have to be renovated 'anyway', i.e. buildings with poor energy performance, the IEA has developed a method for cost-effective energy and carbon optimisation [4] and a tool to support decision-making [5] in the building renovation process [6]. As highlighted in [3–7], energy issues related to buildings are particularly felt throughout Europe and also in Italy, where over 85% of structures were built before the 1990s and many energy strategies have been developed to improve their quality.

Buildings are currently responsible for more than 30 Mtoe of national energy consumption and, thanks to the national strategies adopted, cumulative energy savings of about 1.3 Mtoe have been achieved (considering all energy optimisation strategies implemented from 2014 to 2020) [7].

Considering this context, energy calculation plays a key role in the evaluation of both energy strategies and energy savings. For example, integrating LCA with energy savings calculation would allow not only operational energy consumption to be considered, but rather the life cycle impact of insulation materials used in building renovations. Currently, the regulated energy calculation method at the European level consists of a monthly calculation to produce Energy Performance Certificates (EPCs), based on standard boundary conditions and conventional climatic data. This method is widely used at the national level also for checking energy savings and requirements through energy incentives, such as in the Superbonus 110%. [8].

According to this background, the integration of energy assessment, environmental analysis of insulation materials and its cost evaluation can represent a fundamental step in the renovation process of buildings.

1.1 Research Question

Based on the data, building stock and results provided by a recent study carried out by by Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) [9], the aim of this research is to evaluate of the economic sustanaibility of the most used insulation material for the thermal coating of building envelopes (such us EPS, Stone Wall and Glass Wall) by calculating the economic payback time. The study addressed by ENEA proposes a model to evaluate the energy and environmental impacts of several insulation materials used for the thermal coating of building envelopes by using the standard energy calculation method adopted at the national level, i.e., the monthly calculation method with asset rating (standard evaluation). To achieve this goal several reference condominiums representative of the national buildings stock were defined and used to perform energy simulations in compliance with the calculation method provided by technical regulations [10, 11]. For each climatic zone was assessed the primary energy need of each reference building by adopting the standard monthly calculation method.

1.2 Research Procedure

To achieve the research aim, according with the reference study [9] were defined and collected the following data:

- Defined a building stock with thermal properties typical of existing buildings as representative of the national building stock (based on the data provided by the National Institute of Statistic);
- Defined the most commercial insulation material used for thermal coat (data provide by ENEA)
- Collected data about two configuration of building stock: (1) ante operam, representing the energy consumption of existing buildings and (2) post-operam, corresponding to the energy performance of buildings after envelope refurbishment with a thermal coat by adopting the chosen insulation materials.
- Collected the average cost of energy (€/kWh) in Italy according to ARERA and the cost of the insulation material selected according to the Regional Price List of the chosen region for each climatic zone.

Therefore, the overall costs of intervention were investigated and based on these parameters, economic paybacks were calculated.

2 Reference Buildings and Thermal Insulation Material Definition

The National Institute of Statistics [12], allows to define the national building stock background and introduce several reference condominiums to be used for the present energy simulations.

In Italy, the building units stock (B.U.) is more than 31 million and 79 per cent (approximately) of them are in multiple-family house (MFH) such as small or large condominiums. Almost the 87 per cent of B.U. were built before 1991, i.e., before one of the most relevant energy regulation. Considering this background the energy performance of the national building stock is poor and it has required several energy strategies.

According the national climatic breakdown provided by Decree of the President of the Republic (D.P.R.) n.412/93, Italy is divided in six climatic zones. The greatest number of B.U. (around 48 per cent) are located in the coldest climatic zones, i.e., E and F zones, about 45 per cent in moderate zones, while less than 9 per cent are located in the warmest climatic zones such as in B and A.

Besides, data from the National Institute of Statistics provided limited and low detailed information about building stock. It divides buildings into two, three, and four or more floors, with three floors being the most common configurations.

The average net surface of BU is approximately 85 m2, calculated as the average value weighted on the distribution of the net surface in ranges provided by [12].

According to the data collected, a reference BU unit was considered with a net surface of 85 m2, and a window surface of 10.8 m2 (according to national regulation it has to be greater than or equal to 1/8 of the net surface). Several condominiums were thus defined, considering four reference building units on three floor.

Geometrical characterization of each defined reference building is detailed in Table 1 in terms of net surfaces, heated volume, and dispersant surfaces of walls; the latter represents the vertical surface where the thermal coating can be applied.

Table 1. Geometrical characterization of reference building

N. of floor	N. of BU	Net surface (m2)	Heated volume (m3)	Dispersant Surface (m2)
3	12	1020	3315	527

Thermal coating on external walls was thus hypothesized among the most common used insulation materials (EPS, Stone Wall and Glass Wall) and thicknesses depending on thermal properties of chosen materials and climatic zone (the thickness goes from min 7 cm, zone A, to max 14 cm, zone E). For each climatic zone it was chosen a region (Zone A - Sicily, Zone B - Calabria, Zone C – Campania, Zone D – Lazio, Zone E - Emilia Romagna, Zone F– Valle d'Aosta) Finally, it was collected the cost of the materials (including laying and finishing) by Regional Price List (year 2023) (Table 2).

Table 2. Cost of thermal insulation material per climatic zone.

Thermal insulation material	Cost (€/m2) per Climatic zone					
	A	B	C	D	E	F
EPS	124,23	99,18	79,74	100,15	98,76	121,41
Stone wall (SW)	n.a	109,06	84,7	141,29	116,34	n.a
Glass Wall (GW)	60,93	96,98	101,29	141,15	111	99,4

3 Economic Analysis

In order to carry out the economic analysis, the cost for each insulation material was estimated based on the regional price list of each climatic zone considered (Table 2).

The payback time, intended as the number of years to match the initial cost, was estimated as the ratio between the initial cost for thermal coating realization and the savings resulting from the energy savings after intervention (express in kWh) calculated by ENEA [9] in the study previously cited. Moreover, it was considered the following average national price of 0.501 €/kWh for each energy carrier (data provided by Italian Regulatory Authority for Energy, Networks and Environment (ARERA) [13]). According to data provided by ARERA, 12 BUs in one year face an expenditure of 21.042 € in electricity (1. 754 per BU).

In the following tables are shown the results obtained.

First of all, we have to distinguish between two types of insulation materials, EPS, which stands for sintered expanded polystyrene and therefore falls under the category of synthetic materials, and rock wool and glass wool, which instead fall under the category of mineral/fossil insulation materials [14].

EPS has the highest PBT in most of the climatic zone because of its highest initial cost. It should be noted that ENEA, in its report on the "superbonus 110", highlights that EPS was the most widely used material for thermal insulation of buildings envelope in 2022.

It is worth noting that the colder the climatic zone, the more EPBTs converge, indicating that the affordability of natural materials increases with increasing energy need of buildings.

Materials	Climatic zone	Total cost of intervention for single BU [€]	Saving for single BU[€]	Energy saved after intervention [kWh]	Payback time (year)
EPS	A	5.532	598	1.193	9
	B	4.723	701	1.400	6
	C	3.435	1.029	2.055	3
	D	4.314	1.405	2.805	3
	E	4.255	1.984	3.959	2
	F	5.489	3.542	7.070	2
Stone wall (SW)	A	n.a	n.a	n.a	-
	B	4.699	697	1.391	7
	C	3.649	1.023	2.042	4
	D	6.087	1.401	2.796	4
	E	5.012	2.020	4.032	2
	F	n.a	n.a	n.a	-

(*continued*)

(*continued*)

Materials	Climatic zone	Total cost of intervention for single BU [€]	Saving for single BU[€]	Energy saved after intervention [kWh]	Payback time (year)
Glass Wall (GW)	A	2.625	598	1193	4
	B	4.165	701	1.400	6
	C	4.364	1.030	2.055	4
	D	6.081	1.405	2.805	4
	E	4.728	1.984	3.959	2
	F	4.282	3.542	7.070	1

According to these results, it is evident that when it comes to choose an insulation material a comprehensive (energy, economic and environmental) evaluation has to be done. Due to the high price of EPS, even in warmer climatic zones (A and B), the use of insulation of mineral-fossil origin makes it not only environmentally and energetically sustainable, but also economically.

4 Conclusions

The research aimed at showing the affordability of different thermal insulation materials, focusing on economic aspect. When buildings are under refurbishment intervention with thermal coating, the choice of the material is mostly based on economic analysis, addressing use of cheaper materials.

It has to be highlighted that the results obtained are specific to the considered case study, i.e., strictly related to the assumptions parameters to model it (climatic conditions, building characteristics, energy performance, energy prices, insulation materials prices, etc.) and that they cannot be directly compared with the ones from other studies.

As future development, this research aim at a combined energy, economic, and environmental assessment of thermal insulation materials and to show the importance of considering all these aspects in the building refurbishment process.

Also, a natural and sustainable isolation material i.e. hemp fiber, will be studied and compared with the most used material in terms of economic end environment affordability.

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Preliminary Evaluation Approaches in the Urban Regeneration of Corviale in Rome

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Abstract. Urban regeneration is a multidimensional process involving key social actors, such as civic actors, Third Sector Organizations (TSOs) or spontaneous organizations, who act as catalysts for change, working with administrations to promote initiatives that enable regeneration to go beyond physical redevelopment. Rome's NRRP funded Integrated Urban Plans (IUPs) are an example of such an approach. Specifically, the paper addresses the IUP of Corviale composed by ten interventions aimed at transforming the built fabric and social policies to foster inclusion in the well-known roman suburb, generating lasting impacts in several dimensions. First, a preliminary evaluation of the IUP is proposed as a prodromal stage to define preliminary elements for a future evaluation based on Community Impact Evaluation (CIE). In conclusion, a preliminary structure for a future CIE is proposed in which it is the civic actors themselves who define the key elements in the evaluation process as a social monitoring process.

Keywords: Urban regeneration · civic actors · evaluation approaches

1 Introduction: Urban Regeneration and Civic Actors

Urban regeneration is a transformative operation that affects the structure and use of the city, implying not only spatial and physical changes, as in urban regeneration, but also economic, cultural, social and creative changes in a very complex process [1, 2]. Regeneration projects, therefore, require a radical transformation in the everyday use of spaces, through a shared process aimed at reintegrating the city with society. It is through this profound mutation of urban policies that participatory practices, associations and the Third Sector Organizations (TSOs) become primary interlocutors with public administrations [3]. This new collective rationality is based on the recognition of the centrality of citizens' inclusion in relation to the strengthening of social movements and their capacity to express collective actions [4]. The active participation of citizens in the processes of buildings reuse or public spaces reuse in recent years is defining new stakeholders capable of feeding urban regeneration projects with the public administration (PA). These subjects are often called civic actors and are characterised by their bottom-up nature, by being non-profit actors and by their activities in line with the cultural and social sphere [5]. Moreover, they may be based on formal or informal organisation, they may be spontaneous or self-organised.

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These new urban actors represent an opportunity to define other forms of governance, through models of active participation and social inclusion. Due to their ability to listen to the territories, to bring together people with different visions and values, to be spokespeople for social, economic and cultural instances, and to connect public, entrepreneurial and community realities, they can play a fundamental role both in promoting urban regeneration initiatives and in managing the activities deriving from the interventions that are proposed [6]. The profile of these urban actors is now defined in the literature [5, 7] and the physical effects of their work are progressively becoming tangible in large cities [8] although, their role remains uncertain since, in addition to being temporary, these experiences are new and difficult to catalogue [4]. Among the recent regulatory introductions that try to better identify them is the Single National Register of the Third Sector (SNRTS), envisaged by Article 45 of the Third Sector Code (TSC), active from 2021. All those entities belonging to the Third Sector, i.e. private entities established for the non-profit pursuit of civic, solidarity and socially useful purposes and which, in implementation of the principle of subsidiarity and in accordance with their respective articles of association or deeds of association, promote and implement activities of general interest through voluntary and gratuitous forms of action or mutuality or the production and exchange of goods and services (Law No. 106, 06/06/2016) can be included in this register.[1]

2 Recent National and Local Regulatory Introductions

The reform of the TSC incardinated in Legislative Decree no. 117 07/03/2017 has defined in Article 1 the organisational characteristics for collaborations between public institutions and the third sector, which are increasingly essential for the construction of local welfare systems, understood both as networks of services capable of responding to new needs of the population and also as a set of actions that promote the quality of life of the territories [9]. Article 55 of the TSC regulates the collaborations between these entities and the PA by foreseeing the active involvement of the TSOs through forms of co-planning and co-accreditation, recognising them as stakeholders capable of collaborating in the planning of services.

Co-programming is aimed at the identification by the PA of the needs to be met, the interventions needed for this purpose, the modalities of their realisation and the available resources (Art. 55). Co-programming should generate an enrichment of the reading of needs by facilitating (in the implementation phase) the continuity of the relationship of subsidiary collaboration by producing activities, resources (also intangible), expenditure qualification and the construction of shared and potentially effective public policies.

Art. 55 of the TSC regulates, on the other hand, co-planning, aimed at defining and possibly implementing specific service or intervention projects aimed at satisfying needs defined in the previous Co-programming. Co-design becomes an ordinary instrument for exercising administrative action, no longer limited only to innovative and experimental interventions, through which forms of public-private collaboration are realised.

[1] Third sector entities are: Associations of Social Promotion, Voluntary Organisations, Philanthropic Entities, Social Enterprises and Social Cooperatives, Mutual Aid Societies and other TSOs.

Co-design is a model that is based on the aggregation of public and private resources for the shared planning and design of services and interventions aimed at raising the levels of active citizenship, cohesion and social protection, according to a relationship sphere that goes beyond mere utilitarian exchange (Constitutional Court ruling 131/2020). From these definitions, it is evident that co-design becomes the ordinary methodology for activating collaborative relationships between public authorities and TSOs. The role of these actors in urban regeneration becomes fundamental [8] as they produce social innovation, understood as a set of progressively acceptable solutions to a whole range of problems of exclusion, deprivation, alienation, lack of well-being and also to those actions that positively contribute to meaningful human progress and development, through forms of sustained collective action based on common purpose and social soundness [10].

3 The Integrated Urban Plan (IUP) of Corviale

The implementation of second component "Social infrastructure, families, communities and the third sector" included in the fifth mission "Inclusion and cohesion" of the National Recovery and Resilience Plan (NRRP) allows the financing of Integrated Urban Plan (IUP) investment (M5C2.2), allocating EUR 2.92 billion for the project execution in Italy. The Metropolitan City of Rome, beneficiary of 330,311,511 €, frames the three candidate interventions: Polo del Benessere Santa Maria della Pietà, Polo della Sostenibilità Tor Bella Monaca and Polo della solidarietà Corviale.

Funded with 50,043,779.00 €, the IUP of Corviale aims to promote social inclusion through the activation of a combined action by the urban fabric transformation, social policies and local community development by promoting an inclusive environment for the diverse generations. The IUP of Corviale sets up next to the medium-density urban system and in correspondence of the Corviale public housing building about 1 km long and designed by architect Mario Fiorentino. The IUP aims to integrate and complete the current urban processes and building interventions, such as the construction of 103 new apartments on the fourth floor (previously occupied by families), the Proximity market square of the Regenerate Corviale project, the construction of the new football pitch, the energy efficiency and recovery project for the main building and the redevelopment of the Farmer Market. The IUP consists of ten interventions, divided into five areas of implementation, which are briefly described below.

Area C1 is divided into the interventions C1.1- INCIPIT Business Incubator Redevelopment and C1.2- Campanella Civic Centre. It involves work on two buildings, the first which is a disused building for which it is planned to renovate the building's internal courtyard and reorganise the internal distribution to be used as a headquarters for Community Cooperatives. The second include the maintenance of the Renato Nicolini Library, the Vocational Training Centre, the Work Orientation Centre, the Time Bank, dining areas and new interior spaces dedicated to co-working. For both buildings there are plans for seismic improvement of the reinforced concrete structures, energy efficiency through the renovation of the facades, roofing and replacement of windows frames.

Area C2 is divided into interventions C2.1- Cavea and Arts and Crafts Square (Fig. 1) and C2.2- Header Trancia H. The first intervention concerns the system of public spaces connected to the new entrance of part H (the mixed building that is positioned at 45°

with respect to the main body of the Corviale building) by an inclined plane to be used as a ramp to connect to the equipped green areas and the redevelopment of the artists' workshops present today, formalizing the activities and regularisation of the properties between the Municipality or Rome and Lazio Region. A second intervention is planned on the head of the part H building, informal headquarters of the craftsmen's association Lustri Restauro Mobili, active as a day centre for alternative measures to detention. For this building it is planned to restructure the building and formalise the current premises on the ground floor and to set up the exhibition space for the associations and new post-intervention actors in the shopping gallery, while the socio-cultural hub for contemporary Arts and Crafts, Corviale - Arvalia is planned to be located on the upper floors.

Area C3, corresponding to intervention C3.3 Completion of the sports hall in Maroi Street and of the sports park, provides the fulfilment of the sports hall with grandstands for approximately 700 spectators begun in 2011 and never completed, and the redevelopment and recovery of the neighbouring unused public area with a sports vocation.

Fig. 1. View from the cavea and new connection with the square.

Area C4, named the park system, is divided into intervention C4.1-East Park, aimed at improving the wellbeing of the neighbourhood's inhabitants with the restoration of pedestrian and bicycle paths and the resurfacing of a driveway section, the removal of visual barriers and the planting of tall trees, and intervention C4. 2- West Park aimed at securing and reclaiming the valley area and redeveloping the agricultural ruin on the ridge in front of Corviale to create a centre dedicated to the study of the biodiversity of the agrarian landscape.

Area C5 includes the interventions C5.1- Trancia H commercial gallery, C5.2- Energy Recovery Residences Trancia H, and C5.3- condominium halls. The first includes the recovery and regularisation of the activities in the pedestrian walkway at the level-base of the part H building, with reconstruction of the accesses and paths; the second aims to the energy efficiency of all the levels of the building and, in the end, the recovery of three former condominium halls inside the Corviale building, one of which is to be dedicated to the Corviale memory museum.

The interventions described above aim to urban regeneration and to grafting the community-building processes; therefore, among the immaterial actions included in the interventions is the Corviale City Laboratory[2] (CCL). The Laboratory main mission concerns the social accompaniment of families and the social accompaniment of the artist communities in the Arts and Crafts Square, as well as the empowerment activities of the local community. The involvement of the settlement stakeholders concerned the definition of innovation services (through preincubation, incubation, co-working, acceleration, technology transfer and public-private-community co-design), community services (through the accessibility of public places and services, the social inclusion of people with economic and psychological disadvantages the socio-cultural integration of the neighbourhood's inhabitants and users) and cultural services (through circuits such as libraries, museums, cultural associations, academies, orchestras, artists, theatres, and innovative economic operators, SMEs, start-ups and civic creativity up to support services for families and new generations, such as youth programmes of cultural exchange, including international ones, after-school and playgrounds).

Nowadays, the IUP of Corviale is at an intermediate stage: from the point of view of the physical transformation, the finalisation of the executive projects is under way with the imminent start of construction works, while, from the point of view of the social process, the Co-programming tables with the entities already identified by the Call for Proposals of the Municipality of Rome are under way, in accordance with the regulations described in the previous paragraph.

4 A Preliminary Evaluation of the Corviale IUP

The complexity settled by interventions of the IUP aspires to trigger on the challenging territory, and the desire to set up from this stage an *ex-post* impact evaluation process, requires a preliminary evaluative analysis finalized to a systematization of the relationship between the main elements (Goals of the Plan, Plan Interventions, The asseDimensions of Impact and Stakeholders). The assessment is formulated through analysis of the Plan report and consultation with the CCL and is based on the following three steps.

The first phase is functional in systematizing the goals of the IUP through an assessment aimed at identifying the prevailing impact dimension that each goal is potentially capable of generating. The complexity implies a multidimensional consideration, since urban regeneration needs an integrated vision, which aims to generate lasting changes

[2] Third Mission Laboratory of the Department of Architecture at Roma Tre University set up in 2018. It aims to accompanying the project for the physical transformation of Corviale with actions and social policies capable to support those involved. Professor Francesco Careri and Professor Giovanni Caudo are the Scientific Directors of the CCL.

in economic, physical, social and environmental terms [11]. Therefore, impacts are considered in the following dimensions: Fiscal (Fi), Financial (F), Economic (Ec), Environmental (En), Social (S) and Cultural (C), [12]. For each goal, a judgment is made regarding the dimension of impact (main, secondary or negligible/zero) in which it is presumed to act (Table 1). The recognition of goals allowed the aggregation into three systems: 1) Goals related to the settlement system (St); 2) Goals related to the service system (Se); 3) Goals related to the socioeconomic system (So).

A first reading shows that the goals for the Settlement System will tend to have a prevailing impact on the economic and environmental dimensions; the goals for the Service System will tend to have a greater impact on the economic dimension; and, finally, the goals on the Socioeconomic System (in addition to having impacts on the system to which they refer directly) consider different cultural aspects. It is evident how the Plan, in its overall regenerative transformation action, aspires to generate impacts prevalent in the economic and social dimensions and secondarily in the others. The financial dimension appears in this first analysis to be less fundamental since all interventions involve public assets, in an urban fabric that is almost entirely publicly owned. Finally, compared to what is suggested in the reference literature, no impacts of a fiscal nature are identified in this first reading.

The second stage of preliminary analysis relates the Plan Interventions to the identified Dimensions of Impact in order to assess the contribution of projects to impacts in the various dimensions (Table 2). It is considered premature to predict a measure of impacts in their relative methods of measurement, deferring this to future impact assessment and conducting an analysis on the basis of a three-point qualitative scale, rating the Plan Intervention as: high impact, medium impact, and minimal or no impact.

This assessment of interventions confirms the general vocation of the IUP, namely, to address with physical transformations social and economic aspects, both an overall balance of interventions distributed so as not to neglect environmental and cultural aspects. Each intervention seems to aspire to generate at least a major impact in one of the dimensions considered and an average impact in at least two other dimensions.

The last phase of this preliminary analysis coincides with one of the first operational phases of Lichfield's Community Impact Evaluation (CIE) [13], namely, the identification of the subjects on which the impacts will be measured, divided between active (producer/operator) and passive (consumer) actors, shown in Table 3.

5 Conclusions: Toward Impact Evaluation as a Social Monitoring Process

The current process, assisted by the CCL in the context of the co-programming tables, seems to pose as an ideal environment to set up an impact evaluation of the IUP, based on a broad social and participatory process, whose goal is to verify and monitor the effectiveness of the Plan, through the reading of the impacts on different community groups, also employing multicriterial and inclusive procedures [14, 15]. The conceptual framework for the following evaluation phase is that of Lichfield's CIE [13] for its ability to consider heterogeneous impacts produced by a project on an entire community [16]. Preliminarily setting the lineaments of the change process could be a useful prodromal

Table 1. Assessment of IUP goals in relation to impact dimensions.

Goals of the plan		Dimensions of impact				
a) Settlement system		**F**	**Ec**	**En**	**S**	**C**
St1	Eco-restoration, renovation, and re-functionalization of existing public building structures	•	•	X	0	0
St2	Implementation of sports facilities and community centres for local communities and neighbouring areas	X	•	0	X	X
St3	Connecting the natural areas to the east and west interrupted by the large building-neighbourhood	0	X	•	0	X
St4	Improving energy efficiency in buildings	X	•	•	0	0
St5	Increased usability of green areas and public space and accessibility for people with reduced mobility	0	•	0	•	X
St6	Reconnecting natural areas with the park system at the urban scale and with ecosystems in the metropolitan area	0	0	•	0	0
St7	Environmental and landscape redevelopment and enhancement with restoration of degraded areas	0	X	•	0	0
St8	Improved housing conditions for residents	•	X	0	•	0
St9	Implementation of a capillary network between neighbourhoods and local services, green areas, school and cultural services, socio-assistance, pharmacies, parishes, etc	0	•	X	X	X
b) Service system		**F**	**Ec**	**En**	**S**	**C**
Se1	Completing and implementing the system of public services and overcoming infrastructure deficits	0	•	0	X	0
Se2	Increasing services and neighbourhood commerce through the introduction of new sociocultural principals	X	•	X	•	0

(*continued*)

operation to the ex-post evaluation of what will actually take place [17], considering

Table 1. (*continued*)

Goals of the plan		Dimensions of impact				
Se3	Development and implementation of services for business incubation and acceleration	0	•	0	X	0
Se4	Regularization of housing/associative realities squatting in apartments or commercial premises	•	X	0	X	0
Se5	Regularization of uncertain ownership situations suspended between Municipality of Rome and Lazio Region	X	•	0	0	0
c) Socioeconomic system		**F**	**Ec**	**En**	**S**	**C**
So1	Facilitation of social and entrepreneurial revitalization processes with community and cooperative forms	X	•	0	•	0
So2	Strengthening the social and solidarity economy and neighbourhood cooperative economy	0	•	0	•	X
So3	Fostering inclusion and protection of fragile and weaker groups with improved social conditions supported by local communities	0	X	0	•	X
So4	Promoting sports practice as an element of well-being and quality of life	X	0	X	•	X
So5	Improving the quality of life and work of residents	X	X	0	•	X
So6	Fostering the development of a social and solidarity economy network to support TSOs activities for the management of spaces and buildings	0	•	0	•	X
So7	Integrating the expertise of different categories of civic, social, cognitive, public and private actors	X	X	0	•	0
So8	Improved sense of safety, security and transformation of neighbourhood image	0	X	0	•	X

(*continued*)

that the evaluation represents the thermometer of the strategic directions taken by urban regeneration processes [18].

Table 1. (*continued*)

Goals of the plan		Dimensions of impact				
So9	Consolidation of culturally active realities capable of building a sense of belonging, social cohesion and promotion, and cultural revitalization of the neighbourhood	X	X	0	X	•
So10	Improved sense of community and memory of places	0	0	0	•	•

• Primary impact; X Secondary impact; 0 Negligible or no impact

Table 2. Relationship design interventions with impact dimensions.

Plans intervention		Dimension of impact			
		F	Ec	En	C
C1	P1. INCIPIT Business Incubator Redevelopment	X	•	X	•
	P2. Campanella Civic Centre Redevelopment	X	•	X	•
C2	P1. Redevelopment of Cavea and Arts and Crafts square	X	X	X	•
	P2. Building Recovery in Header Trancia H	X	X	X	•
C3	P1. Completion of Sports Hall in Maroi street	0	•	0	X
C4	P1. Est Park Realization	0	X	•	X
	P2. West Park Realization	0	X	•	X
C5	P1. Recovery Trancia H commercial gallery	X	•	X	•
	P2. Energy Recovery Residences Trancia H	•	•	•	0
	P3. Renovation of condominium halls	0	X	X	•

• High impact; X medium impact; 0 minimal or no impact

The subjects referred as TSOs in Table 3 represent a heterogeneous group of civic actors engaged in the co-programming process and officially identified by the Municipal Call for Proposals, pursuant to the national regulations previously described. Explicating the interest of TSO actors in the individual intervention based on their mission and location (Table 4) provides a greater understanding of the ongoing process.

Table 3. Framing of key actors.

Actors		Type	Current role in the IUP	Relationships to spaces, areas, and buildings
ACTIVE ACTORS	Rome Metropolitan City	PA	Project Funder	-
	Municipality of Rome	PA	Developer/Decision maker	Owner of areas, housing and buildings
	Lazio Region	PA	Decision maker	Owner of areas, housing and buildings
	Territorial Housing Agency (ATER)	Pu	Developer/Housing manager	Housing and building manager
	Local companies	Pr	Business in area	None/Renters/Building or space assignee
	Third sector organizations (TSO)	TSO	Co-design, management of services	None/Renters/Building or space assignee
	Shopkeepers	Pr	Co-design	Renters/assignees
	Local artisans/Artist	Pr/TSO	Co-design	Renters/assignees of spaces/squatters
PASSIVE USERS	Corviale building inhabitants	Pr	Participation processes	Users/tenants/squatters
	Inhabitants building Trancia H	Pr	Participation processes	Users/tenants/squatters
	Sports clubs	Pr/Pu	Co-design, management of services and activities	Tenants
	Workers in the area	Pr	Participatory processes	Users
	Nearby inhabitants	Pr	Participatory processes	Users
	Corviale building inhabitants	Pr	Participatory processes	Users/tenants/squatters

PA: Public Administrations; Pr: Private actor; Pu: Public actor;

The projects that seem to attract the most interest from TSOs are definitely the business incubator and civic centre (C1.1 and C1.2), the Arts and Crafts Square (C2.1), and the East Park (C4.1). Understandably, less attractive to the third sector is the public housing efficiency intervention. There is not a Plan Intervention on which opportunities for involvement or interest by the TSOs involved do not fit. As anticipated, taking

Table 4. TSO officially involved in the IUP process.

TSO actors			Plan interventions							
	C1.1	C1.2	C2.1	C2.2	C3.1	C4.1	C4.2	C5.1	C5.2	C5.3
S1. SPEHA Fresia	•••	•	•	•	–	–	–	•	–	–
S2. Segui il Colibrì	–	•	–	–	–	•••	•••	–	–	–
S3. H-anno Zero	••	••	•	•	•	•	•	–	–	•
S4. Eudec 50	•••	••	•	•	–	–	–	•	–	••
S5. Fari nella Nebbia	–	•	–	–	••	•••	•	–	–	–
S6. Corvialedomani	•••	•••	•	–	•••	••	•••	••	•	•
S7. Stamperia Tevere	••	••	•••	•••	–	••	–	•••	–	••
S8. ANTEAS Roma	•	••	••	–	••	••	–	•	–	•
S9. Comunità sant'Egidio	–	••	–	–	–	–	–	••	–	•
S10. Gli Asini	•••	••	••	•	•	–	–	–	–	–
S11. Acquario 85 ONLUS	•••	•••	•	–	•	••	•••	••	•	–
S12. Calciosociale	•	•	–	–	•••	•••	•	–	–	–
S13. Artestudio	•	••	•••	•••	–	–	–	–	–	••
S14. Arci Solidarietà	•	•	•	•	–	•	•	••	–	–
S15. AUSER Lazio	–	••	••	–	••	•••	••	••	–	•
S16. Mitreoiside	•	•••	••	•	–	••	•	•	–	•••
S17. Solid Roma	•••	••	••	•	–	•	–	••	–	••

••• Primary role; •• Secondary role; • Possible role; (–) No role

advantage of the favourable moment of dialogue between PAs, citizens and TSOs, and the interests of the latter subjects in the projects and activatable services, the impact assessment could represent a social monitoring process that includes both the sharing of impact measurement methods and subsequent monitoring steps. The starting point is a matrix constructed, for each Plan Intervention, based on the CIE method (Table 5).

What the paper wants to propose in conclusion is that for each dimension of impact, a set of indicators can be identified, which meets two requirements: i) it can respond to the interpretation of the phenomenon (technical aspect); ii) it can best interpret the interest, mission and goals of the community (social aspect). Among impact measurement methods (monetary, nonmonetary, qualitative or quantitative) starting from a technically congruent set, a set that is shared by stakeholders can be achieved.

In the field of sustainability, community involvement in the choice of the set of indicators, the result of a simultaneous bottom-up and top-down process, produces the triggering of extra benefits on the whole process [19, 20]. Several case studies illustrate how the participatory process has helped generate exhaustive sets of indicators, triggering processes of community empowerment and collective commitment to transformation processes [21]. Social Impact Assessment (SIA) also analyses impacts on

Table 5. Impact matrix model for each planned Plan Intervention.

			Impacts				
	Actors		F	E	En	So	Cu
PLAN INTERVENTION N	ACTIVE ACTORS	Rome Metropolitan City					
		Municipality of Rome					
		Lazio Region					
		Territorial Housing Agency (ATER)					
		Local companies					
		Third sector organizations (TSO)					
		Shopkeepers					
		Local artisans/Artist					
	PASSIVE ACTORS	Corviale building inhabitants					
		Inhabitants building Trancia H					
		Sports clubs					
		Workers in the area					
		Nearby inhabitants					
		Corviale building inhabitants					

people and their daily lives by going so far as to define a process during which community involvement, also contemplating the more structured use of what emerges from new communication platforms (social media) regarding inhabitants' perceptions [22] and the choice of appropriate sets of criteria and quanti-qualitative indicators become central [23].

Processes of this kind require the application of techniques and procedures capable of holding together expert viewpoints with those of the community involved [20] in order to ensure the quality of the proposed indicators and related monitoring of impacts. To this end, the use of deliberative procedures would be ideal, in the course of which through the solicitation of rational and reasonable arguments, and informed and conscious participation, subjects seek to convince each other until a shared decision is reached [24]. The goal, in addition to raising awareness to enable people to make decisions that affect the collective interest, is the overcoming of individual preferences in a social process in which collective judgments and choices are constructed.

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"Targeted" Model of Social Housing: An Operational Declination of the Break-Even Analysis for Determining Rents

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Abstract. Over the past 30 years, in social housing policies in Europe there has been an increasing involvement of the private sector due to the widespread inability of institutions to guarantee public commensurate to the need. Private real estate operators have been entrusted with the task of social housing; the public intervention has been limited to rent control (rent capping). This paper presents the results of a Reresearch commissioned by the National Association of Building Constructors (ANCE), Lazio section, with the aim of researching the conditions of economic-co-financial feasibility, expressed in terms of rents, of a social housing intervention, in the Lazio Region so that it could be carried out by private real estate operators. The results obtained from the experimentation are also analyzed in relation to their sustainability for the so-called "gray band" of the population, to which social housing is aimed.

Keywords: Social Housing · Break-Even Analysis · Capped Rent

1 Introduction

In Europe there is no univocal definition of "social housing" with a strong heterogeneity of policies and instruments put in place by each country, reflecting the strategic priorities assigned to housing policies for the weaker sections (or "gray band") of the population [1].

However, analyzing the different "conceptions" of social housing in Europe, it is possible to recognize a target that accumulates the policies in this regard conducted by the various Countries, which in short consist of promoting interventions and initiatives aimed at making available housing with rents (or purchase prices) below the thresholds of free market; it should be noted that the potential audience of population interested by social housing takes on different characterizations from Country to Country (in short, it depends on the income thresholds for access to social housing).

Historically, housing policies for the so-called "weak segments of the population" have been carried out predominantly and widely in the countries of the European Union by Public Institutions and therefore with public resources. It is since the 1990s of the

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20th century that the private sector has progressively increased its role in social housing policies significantly, thus assuming the role of the implementer of social housing initiatives, with the public sector remaining in charge of determining capped rents.

Despite the heterogeneity of applications and the different levels of public-private interaction, the multitude of applications adopted by the different European Countries with which social housing initiatives are implemented, according to the functionalist approach proposed by CECHODAS (European Federation of Public, Coopertives & Social Housing) can be traced back to two reference models [2]:

1. the "targeted" model, which assumes the identification of specific targets and a propensity to rely on market capacity, admitting the need for public intervention to ensure access to housing for excluded households;
2. the "universalist" model, which is based on the principle of the public entity's responsibility to ensure decent housing at affordable prices for everyone.

This paper illustrates some results of a Research commissioned by the National Association of Builders (ANCE), Lazio section, to the Department of Architecture of the University of Florence and focuses on a specific case of the "targeted" model related to social housing interventions of an exclusively private nature, which are usually subject to rents capping. Specifically, it is intended to propose the application of the Break-Even Analysis (BEA) for the determination of a rent that is lower than free market rents but that allows the operators in the sector to achieve at least, the break-even of the initiative [3, 4].

In order to test the operational capacity of the declination of the proposed BEA, an experiment was carried out on the Lazio Region; it was chosen to test the BEA in the Lazio Region since with article 3 ter of Regional Law No. 21/2009 (law aimed at encouraging the regeneration of the existing assets or the urban adaptation of urban plans yet to be implemented) there is the obligation to associate with private interventions in the free market, the production of social housing to be subject to a capped rent.

Despite such regulatory provisions and although article 3 ter of Regional Law No. 21/2009 has been copiously implemented, most social housing initiatives have not in fact been started because the regulatory provisions set forth in Regional Regulation No. 18 of 2012 relating to the determination of the capped rents, has in fact inhibited real estate operators in the sector from initiating such initiatives.

2 Types of Social Housing: A Concise Review

A common definition in the European Union of social housing has been made by the CECHODAS, which in 2005, referred to social housing as "housing solutions for those households whose needs cannot be met under market conditions and for which there are allocation rules". In 2010 the European Commission placed greater emphasis on the organizational and management profile of social housing interventions and the aspects of social cohesion and integration of social housing users [5]: "the development, rental/sale, and maintenance of affordable housing and its allocation and management, including eventually the management of housing complexes and neighborhoods; may include support services involved in housing programs or resettlement of specific groups or debt management of low-income households".

Deepening on what was anticipated in the introduction, the operative models/approaches by which social housing policies are implemented are quite diverse and depend on the variety of actors implementing the housing and/or housing in social housing consists of Local Authorities and corporations with public participation, private non-profit or cooperative interest companies and Institutions, and private companies [2].

The decentralization of responsibilities, found over the past three decades in favor of Regional and Local Authorities, has led to the gradual attenuation of the role of Central Governments and greater involvement of the private sector, within a stricter regulatory framework than in the past. It consequently follows, therefore, that many solutions adopted in Europe are the result of the increasingly close interaction between the public sector-usually municipalities, directly or indirectly, through publicly or municipally owned companies-and the private sector-both in the form of companies specializing in the investment sector, and in that of entities more closely linked to nonprofit environments [2].

From a brief examination of some European experiences, the universalistic approach is mainly recognized in Northern European Countries. For example, in the Netherlands although the implementation of social housing interventions is delegated to specific local institutions, the central government plays a guarantee role; in Sweden, on the other hand, policies on social housing coincide with those of public housing promotion, with the management of housing in the hands of municipalities.

Several states, on the other hand, adopt both approaches: this is the case, for example, in France, Germany, Austria, Italy, and Spain. France and Germany decline social housing through a targeted model, but offer both generalist solutions - binding access to supply only to citizens below certain income thresholds - and residual solutions - providing for preference in the allocation of housing to individuals with special social protection needs. The implementers are typically public, while allowing room for private nonprofit and residually for-profit operators to operate, in France; while they are essentially private in Germany. Along the same lines, although not having renounced direct intervention as well, France is moving, through savings funds (with regulated interest rate and not subject to taxation) collection is carried out for the realization of social housing operations, which also benefits from indirect public interventions such as low-interest loans and public guarantees. Of particular interest in Germany is the promotion of social housing through public subsidies to private operators to incentivize the implementation of new interventions or the redevelopment of existing assets, which usually take the form of "premiums" and/or tax breaks for private companies operating in the social sector through the adoption of housing allocation solutions that discriminate on the basis of the applicant's income, or by adopting capped rents for well-defined periods. Unlike many other European Countries, the Spanish model targets mainly the ownership segment and minimally the rental segment. Public intervention is concentrated in new construction and redevelopment through direct subsidies finalized to low-interest loans conditional on compliance with special construction conditions (regarding size and quality of housing) and sales conditions (at lower-than-market prices in favor of individuals with incomes below certain thresholds). In Austria, social housing is associated with limited-profit or popular initiatives and is characterized by strong interaction between the public (from the central to the local level) and the private sector (builders, landlords, and financial institutions), with a system based predominantly on the regulation of ownership and rents. Approximately half of the housing in Austria receives some form of public subsidy, and half of this falls into the category of social housing, while the remainder is distributed between leases and private properties traceable to private investors, in accordance with nonprofit operations subsidized by the public sector. In Italy too, a two-pronged approach is discernible; completely public intervention, by specific Public Companies, has historically been flanked by the possibilities offered by subsidized housing, in which private intervention, depending on the case, assumes different relevance. As in Germany, the more recent season of social housing has seen an increase in the role of private actors in the production of social housing, including through urban planning incentives (premiums).

Instead, the targeted approach is recognized in many Eastern European countries, but also in states such as Portugal, and Denmark. Eastern European countries, with the exception of Poland and the Czech Republic, have preferred, since the 1990s, to adopt the extreme solution of large-scale privatization of the public housing stock, reducing current social residential housing to a residual portion of what was the stock in the disponsibilities of Local Authorities during the socialist regime. In Portugal, the subjectors implementing the interventions are predominantly public in nature, as are the financial resources. The case of Denmark can be considered "targeted" although the concept of social housing takes on different connotations than in the other analyzed member states: here there is an overlap of the concept of social housing with that of co-housing.

In contrast to diversified implementation models in EU member Countries, it appears more homogeneous that the mechanism for selecting beneficiaries, although with differentiations due to national legislation, is always based on: (i) income status of households, albeit with differentiations on the amount of income to be eligible for social housing; (ii) "specific need", based on health conditions, household numerosity, age, and membership in particular professional and productive sectors (in the latter case, housing policy is intertwined with industrial policy in order to facilitate the establishment of certain professional figures in localities and productive realities particularly in need of specific human capital) [6, 7].

At the conclusion of this paragraph, it can therefore be noted that social housing policies in Europe are those aimed at providing access to housing to those who do not have the income/wealth capacity to access the free market; all of this, albeit with different declinations and audiences from Country to Country. With regard to the involvement of the private sector, it can be noted that this has sensibly increased since mainly the 2000s: in the Europe-15, in fact, we are witnessing a steady decrease in the di- direct participation of the public sector (including Local Authorities) in the implementation of new initiatives, with a greater concentration of energies and resources on the management of existing assets, to the benefit of private initiative [8].

3 Operational Declination of Break-Even Analysis for the Determination of Rents

In Italy, for several years, a component of Cost Volume Profit Analysis (CVPA) - the Break-Even Analysis (BEA) - has been recognized to have a full scientific and operational autonomy and it has been commonly used. BEA allows the verification of the conditions of financial expediency to undertake an investment or rectify, for example, one already undertaken. The main usefulness of BEA lies in its ability to examine the impact of prices and costs in relation to profit [9]. Indeed, BEA summarizes the effects of changes in an organization's volume of business on its costs, revenues, and profits. It can be extended to cover the effect on profit of changes in sales prices, service rates, costs, income tax rates, and the organization's product or service mix. It is thus an evaluation tool that can provide a company's management with a comprehensive overview of the effects on revenues and costs of all kinds of short-term financial changes. Although the word profit often appears in the scientific literature associated with BEA, this technique can also be effectively used for the evaluation of social-impact initiatives that are not preliminarily focused on the pursuit of profit, but on the practicability and thus feasibility of the programmatic/planning forecasts associated with a production-industrial initiative [10, 11]. On the basis of these premises, the BEA thus makes it possible to identify the parameters that make an initiative "stable"; in the case at hand, therefore, it has been applied by proposing an operational declination specially calibrated for the specificities of a housing production intervention that, while guaranteeing a social function through a capped rent, must be implemented by a private entity, without the support of any public contribution. In fact, the operational declination poses the rent as an unknown, taking care to consider in the calculation, specific parameters for interventions that guarantee the return of the production costs necessary for the implementation of the housing itself. As for the resolution of the "estimative questions" necessary to implement the BEA (cost estimation, cap rate, market value) are addressed by resorting to the traditional (depending on the case, direct and indirect) estimative procedures.

In technical terms, the "break-even" is an unknown q*, i.e., the minimum amount needed to repay fixed and variable costs, thus ensuring ordinary profitability in market terms for a real estate developer. In traditional BEA, known fixed costs, unit variable costs and unit revenues, the quantity of q, which becomes q* by which equilibrium in the composition of fixed and variable costs and revenues (without extra-profits) is achieved, can therefore be estimated through (formula 1):

$$q* = \frac{FCt}{Pu - VCu} \tag{1}$$

where FCt is the total fixed costs, Pu is the unitary prices and VCu is the unitary variable costs.

Where q* is not unknown, but is a defined parameter (known projects, e.g., approved) one can rewrite formula 1 as (formula 2):

$$FCt + VCu * q = Pu * q \tag{2}$$

If you want to reason in terms of unit product, you can assume q = 1 and formula 2 becomes (formula 3):

$$FCu + VCu = Pu \tag{3}$$

Considering that, in a settlement transformation intervention, Pu can be associated with the unit market value of leasable and/or saleable assets, formula 3 becomes (formula 4):

$$FCu + VCu = MV \tag{4}$$

In order to fully understand the meaning of market value (MV), understood both as a parameter (value) that becomes price at the time of alienation of a real estate, and co-meaning equivalent capital generated by a lease, it must be considered that income, in financial mathematics, is configured as a deferred annuity, i.e., a capital (in addition to income can be considered such depreciation allowances, credits, etc.) regularly available at the end of each year, which may be unlimited or limited depending on whether or not it continues to occur for a number of years above 60–80. If to the above described by formula 4 we substitute for the undifferentiated savings and its annual use/interest price a property of value VM and its net future, ordinary, average, and continuing income Rn, we obtain formula 5, which represents the traditional analytical-indirect procedure for estimating Market Value (income capitalization):

$$MV = \frac{NI}{r} \tag{5}$$

where I is the net income and r is the cap rate.

Formula 5 can therefore also re-written sa formula 6:

$$FCu + VCu = \frac{NI}{r} \tag{6}$$

On the said formula, it should be noted that the estimative discipline, over time, has undergone some evolutions that make it possible to work, in the capitalization of incomes, both with net incomes and with gross incomes, taking care, however, to consider, in the first case capitalization essays referring to net incomes, in the second case referring to gross incomes. In more general terms, formula 6 can therefore be generalized into formula 7:

$$GI = (FCu + VCu) * r \tag{7}$$

where GI is the gross income.

This declination of the BEA allows, in lieu of the identification of the break-even point, the identification of the "break-even rent" in function with the costs associated with the intervention and the specific capitalization essay for the urban area in which the initiative falls.

In short, it involves addressing and answering three estimation questions: estimation of Cfu, estimation of CVu, and determination of r.

Considering the application specificity of BEA centered on unitary parameters, fixed costs can be considered as incidence versus variable costs [12]; formula 7 can therefore be transformed into formula 8:

$$\begin{aligned} GI = (C_a + C_{te} + C_{ia} + C_{sa} + C_{up} + C_{us} + C_{cc} \ + \ C_{tc} \\ + C_{st} + C_{oc} + C_{oc} + C_{ai} + C_{of} + C_{up} - GF) * r \end{aligned}$$

– C_a related to the market value, if applicable, of the buildings/intervention area;

- C_{te} related to the technical costs of constructing saleable buildings;
- C_{ia} related to the costs of suitability of the area;
- C_{sa} related to the costs of outdoor private area development;
- C_{up} related to urbanization costs (equal to or higher than primary urbanization charges);
- C_{us} relating to secondary urbanization charges;
- C_{cc} related to contribution on construction cost;
- C_{tc} related to costs of works to be surrendered, non-locatable/saleable;
- C_{st} related to technical expenses related to fixed costs;
- C_{oc} related to marketing charges;
- C_{ai} related to other costs, including contingencies;
- C_{of} related to financial charges;
- C_{up} related to the profit of the promoter;
- GF related to grant funding.

Unit sales prices (Pu) are concerned with the proceeds from the sale of buildings that can be disposed of with the intervention (or even rented out, if rental income is capitalized). For a quick and still effective implementation of the model, they are estimated in a synthetic-direct manner taking into account data provided by databases that reveal sales prices.

The implementation of formula 18 thus makes it possible to estimate the break-even rent of real estate initiatives; it seems obvious that, if the real estate initiative is social housing, this case will have to be considered in the estimation of costs; all of which is explained in greater detail in Sect. 4 below.

4 An Application on the Territory of the Lazio Region: First Results

The BEA, appropriately declined because of the principles inferable from Art. 3 ter of Regional Law No. 21/2009, was applied with the aim of determining the rents that allow the implementation of initiatives that, while providing for capped rents, are implementable by private operators, without the support of public contributions. The experimentation was extended to the entire territory of the Lazio Region; in this regard, a database was constructed containing about 100,000 data, taken from institutional sources and/or those of recognized scientific caliber such as the Real Estate Market Observatory of the Revenue Agency, the Ministry of the Interior, and ISTAT.

The construction of the database was carried out by taking the micro-zones of the OMI as basic cores; for each micro-zone, with respect to the data made available by the Inland Revenue Agency, additional data were integrated, which allowed to prepare sets of attributes the implementation of traditional, large-scale estimation procedures as a basis for being able to apply the BEA.

Specifically, the database was constructed considering the following data:

1. geographic/demographic: land area, region, province, municipality (and ca-tegory), resident population (if greater than 10,000 inhabitants), band, zone, microzone;

2. estimative: type description, state of preservation, maximum, average, and minimum quotations, type of area considered for quotations, maximum, average, and minimum rents, type of area considered for rental cano-nies, master party expenses (value and percentage), capitalization essay, construction cost (referred to settlement production).

Geographic data were extracted from the Internal Revenue Service's OMI, the Ministry of the Interior and ISTAT.

Estimative data, on the other hand, were extrapolated as follows:

– description type and conservation status, were extrapolated from the OMI of the Internal Revenue Service;
– the maximum and minimum quotations were extrapolated from the OMI of the Internal Revenue Service; the average quotations, on the other hand, were ap-positive;
– the type of area considered for the quotations was extrapolated from the OMI of the Internal Revenue Service;
– maximum and minimum rents were extrapolated from the OMI of the Internal Revenue Service; average rents, on the other hand, were the subject of ap- propriate calculation;
– the type of area considered for rents was extrapolated from the OMI of the Internal Revenue Service;
– manor-part expenses were assumed with reference to the manual-estimated (percentage) and therefore specially calculated;
– the capitalization essay was specially calculated, using data in the OMI database;
– the cost of construction (settlement production) specially estimated by considering, from Typological Price Lists, both the technical cost of construction and indirect costs such as, suitability of the area, primary and secondary urbanization costs/charges, technical expenses, other costs, including contingencies, financial charges, profit of the real estate developer (general manager of the operation), not considered as it is assumed included within the premiums of L.R. no. 21/2009; not considered: contribution on the cost of construction, for the effects of art. 6 paragraph 5 of R.L. no. 21/2009; costs due to works to be surrendered, non-locatable/non-saleable, marketing charges, financing from per-grant funds.

An elaboration of the data in the database was carried out to identify sustaina-ble rents; the incidence of the area was considered by estimating it, through the analytical-indirect estimation procedure of the Transformation Value (TV), using the data in the database and a discount essay equal to the risk-free rates: for each non agricultural micro-area in Lazio Region (where SH can be implemented), a specific parametric value has been defined, depending on the characteristics of the area itself, which in TV reverberates on the values/parameters to be used. The results were processed while maintaining the structure of Regional Regulation No. 18 of 2012, i.e., referring to: Rome Capital, Municipalities with a population of 10,000 or more, Municipalities with a population below 10,000. From the cal-culation of municipalities with a population of less than 10,000 inhabitants, the parameters related to the islands (Ponza and Ventotene) were excluded, as they were considered misleading for the purposes of this application, considering these small towns not affected by the dynamics set forth in Article 3b of

Regional Law No. 21/2009. Based on these considerations, the BEA was applied: Table 1 shows the results of the processing, appropriately rounded.

Table 1. Rents deriving BEA.

Rents (results)			
1	**Roma Capitale**		
	Rent	€/sqm for month	9.90
2	**Municipalities with population equal or greater than 10.000 inhabitants**		
	Rent	€/sqm for month	9.10
3	**Municipalities with population lower than 10.000 inhabitants**		
	Rent	€/sqm for month	9.40

5 Conclusions

The results obtained from the experimentation referred to in the preceding paragraph are sustainable rents for operators who have willingness to start initiatives aimed at the creation of residential housing at a capped rent, for the effects of art. 3 ter of L.R. of Lazio n. 21/2009, but it is not necessarily so for the citizens to whom social housing is intended, that is, those who do not have the requirements to access to public housing, but also have difficulty in accessing the free market.

The fees resulting from the experimentation can already be considered "partly capped": they are in fact "break-even fees" with which to repay the costs of the initiative, thus unlike what is generally expected from initiatives in the free market. However, it should be noted that, from the reading of the results of the experimentation in the light of what emerged in the Research, in the present case referred to the capped rents referred to in Regional Regulation no. 18/2012, but also in general in social housing, based on the actual condition of the construction sector, a diachronic situation is presented characterized by the size of the identified rents that if on the one hand would guarantee the implementation of the initiatives, on the other hand could exceed the threshold of sustainability for low-income families.

A further calming operation, by decoupling the identified rents, on the other hand, while on the one hand would broaden the pool of possible beneficiaries of the initiatives, could condition the activity of private operators. The search for a balance that avoids situations of "non-intervention" and that at the same time has a social scope is certainly a complex operation that probably, must admit greater flexibility than the current regulatory provisions, with the possibility, for example, of introducing a modulation of rents due to the economic condition of households on the basis of income and/or wealth. In this regard, as of December 2023, in which the present Research activity, these reflections have been shared with representatives of the Lazio Region, initiating a path for the revision of the capping rents under R.R. no. 18/2012.

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Applicability of Methodological Approaches and Tools for Detecting Preferences in Housing Choice

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Abstract. The ongoing digital transition profoundly affects people's habits and customs by dislodging them from the place where they have always resided and determining a new demand for housing mobility. The new demand is centered on the choice, conscious and commensurate with one's needs and availability, of the place to live. This phenomenon can significantly affect land-use government activity and requires tools, methodologies and models in order to be understood as the "historicist" approach on which municipalities' planning activities are based is not deemed sufficient. Based on the above, this paper aims to illustrate some initial results of a Project-to of Significant National Interest referred to in the call No. 1409 of 14-9-2022 (PRIN 2022 PNRR) approved by the Ministry of University and Research (MUR) entitled "Housing mobility and digital transition. Evaluation tools and technologies for understanding current and future people's living needs, supporting territorial governance and regeneration processes." This Research project is configured as a prodromal study and investigation activity for understanding, among demographic phenomena, housing mobility, which significantly affects urbanization phenomena on which land use and protection, urban regeneration, and the protection and enhancement of agricultural activity. These topics are of great interest to the PNRR.

Keywords: Land Governance · Sustainable Equitable Welbeing · Digital Transition · Social Research

1 Introduction

The ongoing digital transition profoundly affects people's habits and customs: smart working, digitized services, online commerce, new forms of communication and entertainment on computer platforms, can untie people from the place where they have always resided and determine a new demand for housing mobility centered on the choice, conscious and commensurate with one's needs and availability, of the place to live.

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This change is epochal if one considers that it is taking place for the first time in the history of modern man; the traditional constraints of "home-work" distance that have profoundly influenced people's choice of where to live since at least the 18th century onward, not having been in fact outdated even by the technological advancement of means of transportation, are overcome.

Through the new possibilities for housing mobility opened up by the digital transition, an important opportunity to improve one's housing pro-pertinence, in accordance with the EU's conception and goals of enhancing the well-being of individuals, can be configured. This opportunity consist of the possibility of creating, or choosing, an environment that enables people to fully realize their potential and enjoy their fundamental rights.

On the basis of this premise, housing mobility to improve people's quality of life should be considered among those phenomena destined to grow and stabilize within a new post-pandemic normality. In the post-pandemic period analysts believe that it will occur the growth of flexible, hybrid and innovative work approaches in terms of places and modes of delivery and the online transposition of many activities that until now have been characterized by a "material" dimension.

This phenomenon significantly affects land-government activity and requires methodologies, models and tools in order to be understood: the "historicist" approach on which the planning acts of municipalities are based is considered not sufficient.

Based on the above, this paper aims to illustrate some first results related to the Project of Significant National Interest referred to in the call for proposals No. 1409 of 14–9-2022 (PRIN 2022 PNRR) approved of the Ministry of University and Research (MUR) by D. D. n 1235 of Aug. 1, 2023 and am-mitted for funding by D.D. n 1378 of Sept. 1, 2023, ERC SH - Social Sciences and Humanities, main ERC subfield SH7_7 Cities; urban, regional and rural studies entitled "Housing mobility and digital transition. Evaluation tools and technologies for understanding current and future people's living needs, supporting territorial governance and regeneration processes," and which therefore results among the Research projects funded by the European Union under the Next Generation EU. This Research project is configured as a prodromal study and investigation activity for the understanding, among demographic phenomena, of housing mobility, which significantly affects urbanization phenomena on which the use and protection of land, urban regeneration, and the protection and enhancement of agricultural activity. These topics are of great interest to the PNRR.

Specifically, the first results presented in this contribution consist of the restitution, following an initial literary review, of a set of tools and technologies for analyzing and assessing new settlement needs in the time of the digital society while also providing an initial critical reflection on their usability in the context of citizenship inclusion activities in land government. More specifically, this first phase of the Research is con-ducted by studying tools and technologies drawing on models, procedures, and tools tested in the social research. Although the topic of housing mobility has been addressed for quite some time by scholar-scientists in the social sciences and urban planners mainly in relation to phenomena of economic growth and social integration, the Research Project intends to investigate this phenomenon from a lesser-known point of view related to the search for personal well-being and satisfaction.

2 A Literary Review Summary of Tools Used in Social Research

In science, it is well established that one can acquire even scientific knowledge of social facts [1]. In the social research, particular importance attaches to the study of methods and techniques for constructing the "empirical base" of data and information underlying the research activities themselves. Ricolfi [2] has succinctly summarized the main features that allow us to distinguish two main approaches in social research defined as "quantitative" and "qualitative."

Research in the "quantitative" family is usually qualified by at least three characters:

1. data of a "hard," measurable nature, to be organized into matrix(es);
2. presence of operational definitions of the "modes" of the data matrix(es) (cases and variables),
3. use of statistics or data analysis.

All in all, research more typically ascribed to the "qualitative" family qualifies for:

1. data of a "soft" nature, not measurable, difficult to organize into matrices;
2. non-inspectibility of the empirical base;
3. informal nature of data analysis procedures.

In the literature this bipartition is sometimes also associated with other characteristics that differentiate the two approaches: quantitative techniques can be considered structured techniques, while qualitative techniques are unstructured [3]. These concepts has correspondence with the distinction proposed by Grimaldi [4] between techniques that adopt formal (structured) procedures and techniques that adopt informal (unstructured) procedures: the formal approach enables the production of a "controllable account," while the informal approach takes the form of an understanding/interpretation that consists of "knowing how to enter with success into certain forms of life." Qualitative (informal) techniques that are most widely studied in social research include: live observation, online observation, discursive col- lection, Delphi Method, Focus Group, documentary and content analysis, and experiment.

Live Observation

Live observation consists of the annotation by an observer/researcher of what happens to an observed subject. Observation can be systematic in a structured working hypothesis in which every single action/behavior of the subject observed is recorded. Not all behaviors are annotated but only some, adopting selection criteria dictated by cognitive purposes, based on clearly formulated a priori hypotheses that are to be subjected to empirical verification.

There are different types of observational techniques, depending on the level of control of the observed phenomena and the level of participation of the observed subject:

– naturalistic observation in which the researcher plays no role in defining or modifying the environment in which the action takes place (minimal control) and does not assume a role (minimal participation). Such a case is characterized by low control and a low level of participation of the observed subject;

- participant observer, when the observer assumes a role within a group under study and renounces exercising some form of control or conditioning, this is participant observation. Such case is characterized by low control and a high level of participation;
- laboratory observation insofar as the observer does not participate in an action that is nonetheless under his or her complete control because it has been programmed by him or her to hopefully yield answers to his or her research aims. Such fact-species is characterized by a high degree of control and a low degree of participation;
- interactive observation, when the observer interacts with the observed, according to an action programmed by him. This case is characterized by high control and high level of participation.

The technique of observation opens up the delicate question regarding "intrusion." In naturalistic observation, the observer's control and participation is minimized; this method is configured as non-intrusive. In the case of participant observation, there is non-intrusiveness only if the observer is not perceived as such by the observed. Labora- tory observation and interactive observation, in contrast, are configured as intrusive tools. Observation (from naturalistic to experimental, through all forms in between) can be identified, in the first instance, as the most appropriate method for an effective study of behavior.

Internet Observation

The name might make this technique appear analogous to the one previously analyzed; however, internet observation is a profoundly different and rather recent technique. In internet observation, information and data derived from the networked activity of individuals are used: discussion forums, websites, social networks, photographs and videos posted, use of research engines, which leave electronic traces of activities. As Blank [5] points out, the documents and information found on internet are of a nonintrusive type if they pre-exist the decision to use them or if behaviors are recorded without the "observed" being aware of them. Using the rich documentation of social activity available on the net is thus a significant alternative to traditional techniques used to collect data, because almost every aspect of daily life is reflected somewhere on the net. Moreover, the sometimes only assumed cover of anonymity can contribute to a frankness of expression and behavior that people rarely adopt in live encounters [6]; therefore, the Internet can make even "ephemeral" aspects of daily life that are difficult to record available for research.

Discursive Interviewing

Discursive interviewing is a verbal-oral interaction technique that involves the construction of contexts, more or less formalized, in which the researcher relates to one or more persons whom we can generically call "informants." When the inter-relationship is direct (face-to-face), we may consider that the mode of detection can/should be classified as intrusive. However, we can imagine interviews that are not perceived or presented as such. In fact, informants may be led to believe that they are the protagonists of a spontaneous encounter. It can be understood from this brief introductory description that when we speak of a discursive interview, we are alluding to situations with significant dissimilarities that depend on how the encounter is structured and managed, the number of interlocutors and their role. Regarding the first point, one must take into account the degree of freedom that is allowed in the conduct of the interview and with respect to the topics addressed. Regarding the number, it should be kept in mind that the presenters of the meeting may be more than one, and similarly, the informants may also be one (at a time), or a group. In addition, informants may be a sample of the population that the researcher is interested in studying, but they may also be "privileged" interlocutors, in the sense that by the role they play they possess and could convey specific information crucial to the success of the research. It should be noted that the interview must still have some structuring on the part of the researcher: if poorly structured and there is low standardization of questions and directiveness of responses, the role of the interviewer is not much different from that of a simple observer, re-discussing the possibility that the latter will simply take note of what is being said [7].

Delphi Method

The Delphi method is a technique that makes use of qualified individuals to rationally utilize their wealth of knowledge [8]. The method consists of questioning different experts in a given subject with the aim of arriving, with everyone's input, at a final opinion matured as far as possible consensually. This is achieved by sending the experts specific questions to which they respond in written form, thus marking a difference from the face-to-face interview. The difference, however, is not as significant as po- might seem, because in-person interviews are also summarized in written form "in progress" and/or later transcribed from audio recordings. However, a non-trivial difference remains valid: deferred responses are more "thoughtful" than responses formulated "live," pressed by the interviewer's questions. This is an advantageous difference, however, if the decision was made to use the Delphi technique precisely for the purpose of obtaining a "thoughtful" consensus. After first sending the questions to the participants, the researcher in fact receives the responses, processes them, and brings the results to the attention of the members of the Delphi group, so as to give everyone an opportunity to modify his or her opinion, based on the considerations developed and proposed by the other participants. After a series of iterations of the procedure and possible adjustments to previously expressed opinions, a shared opinion should emerge, at least from the majority of participants. All this happens in a situation that encourages free self-expression since the Delphi method in fact requires that participants do not know the identity of others and, more than anything else, the opinions expressed are not individually attributed when they are disclosed. In fact, it is intended to prevent the emergence of acquiescent behavior on the part of weak elements of the group who might be influenced by the opinion of members influential by scientific prestige or academic position, in the case of experts, or by position of power (economic, political or social), if they are "prominent" members of the community.

Focus Group

A focus group is a meeting of a group of individuals without the purpose of studying, but of making the group itself a useful tool for the production of information, the exchange of experience, and problem-solving. In fact, the group is a producer of ideas, and is the bearer of specific added value, the result of the richness of the interaction process, which often-as they say-exceeds the sum of its parts (the individual members). Focus groups can be in-framed into a typology that takes into account the purpose pursued (to know or decide) and the expected outcome (to produce tools or judgments and information) [9]. Combining the two dimensions results in Focus Groups of four different types:

– exploratory, if one intends to develop survey instruments, as in the example we have just formulated. This objective makes the Focus Group rightfully part of the preliminary background research phase [10];
– normative, if the Focus Group is used to formulate or fine-tune rules and parameters to be used in evaluating projects, policies, or candidates to re-occupy a given role;
– cognitive, if the Focus Group consists of members of the social group under study and it is intended to gather information to be compared ("triangulated") with information gathered by other instruments, qualitative or quantitative;
– evaluative, if the Focus Group is used, for example, to make ex-post judgments about policies or services, as a tool therefore of evaluative research, including using criteria developed in a previous normative Focus Group.

Another particular type of Focus Group can be considered "Brain-storming," which is intended to encourage the emergence of nonconformist and/or innovative positions or ideas. With this technique, the solution to a given problem is sought through intensive sessions of debate and confrontation of ideas and proposals expressed entirely freely by the participants.

Documentary and Content Analysis
In research activity, heterogeneous "documents," produced by a wide variety of authors and for a wide variety of reasons, may be deemed useful by the researcher for research purposes. The construction of the empirical base depends on the researcher's ability to find useful documentation (through his or her own knowledge and access to archives, libraries, video libraries, newspaper libraries, foundations, associations, and other public and private entities, online, etc.), collect it, and sort it so that it is usable. When there is a lot of material available, such as a result of the collection of documents found in the course of networked activities, a problem of selection arises. One can decide whether to proceed with the saturation technique (one exhausts all available material until the information one obtains becomes repetitive) or with some kind of sampling. The documents and content being analyzed take the form of "empirical material" to be considered as sources of information (alternative or additional) about phenomena or events that are the object of study; it is as if the producers of the do-documents being used, assume the role of informants, witnesses, observers, about certain phenomena or events.

Experiment
The family of experiments includes many applications: in general, it is a technique used in special situations and in some fields, in which participants, aware that they are the subject of an experiment, receive a structured and uniform stimulus that must be followed by responses/reactions. In general, the experiment takes place in a controlled environmental situation. In the experiment, it is possible to attempt the attainment of certain results by structuring the stimuli in such a way that the participants do not understand the real purpose intended. In studies of group dynamics, a nearly-experimental situation is

achieved if the researcher, or a suitably trained collaborator, steps into the action to make "pro-vocations" that are the stimulus whose effect is to be studied.

Quantitative (standard) techniques in the scientific literature, on the other hand, include:

Questionnaire

The questionnaire represents perhaps the most widely used survey instrument in social research: it represents a formal (more or less structured) stimulus. Although it can sometimes be noted in the scientific literature that face-to-face interviews and surveys (including by telephone or in a computerized manner) are also considered forms of questionnaires, in the present case we will refer to an instrument of information gathering, mainly in written form, containing a plurality of questions to be answered by the subject to whom it is administered. In this sense, the questionnaire is understood to differ from the survey in the amount of information required. This social research instrument is therefore understood to be associated with self-completion [11, 12]. This entails two problems to be addressed: constructing questionnaires suitable for self-completion and "contacting" the questionnaire with the subject to whom it is to be administered. As for the specific characteristics of a questionnaire suitable for self-completion, it should be considered that, in the absence of an interviewer who asks the questions and writes the answers, there may be a lack of support for advice and explanations on the correct interpretation of the task to be performed. The questionnaire, and the indispensable accompanying explanation sheet, therefore need to be self-sufficient and not give rise to difficulties of interpretation or ambiguity in case of self-completion. As a general rule, it is preferable not to ask respondents for too much effort, and to avoid proposing long and complex questionnaires that could lead to non-cooperation or loss of attention in formulating reasoned responses. Open-ended questions should also be avoided as much as possible, because they require explication of one's own thinking-a much more difficult task than choosing from a list of pre-packaged answers. It may be helpful to adequately motivate the respondent by accompanying the questionnaire with a cover letter that explains the purpose of the survey and appeals to the respondent's sense of responsibility, the social relevance of the issue addressed, or the importance of acquiring certain information. Accomplishment, on the other hand, becomes easier if the questionnaire is aimed at a specific target audience, because in this case it is sometimes possible to invoke, by adequately illustrating them, concrete "category interests" of which the respondent may be aware and may therefore be credible.

Direct Interview

The direct or face-to-face interview is conducted by an interviewer asking specific questions and recording the answers. The location of the interview assumes re- relevance to the reliability of the data and should be defined in a reasoned manner: it may be the respondent's home, place of work, a public place, a particular event. Interviewing people identified through rigorous sampling techniques is the most widely used mode in surveys of greater scientific relevance to achieve a solid representativeness of subjects dealing with the phenomenon under investigation.

Survey

In the survey, questions are asked that are concise, and that involve concise and few answers. Indeed, one should avoid being influenced by the fact that an answer is listed at the beginning (more alert attention) or at the end (fresher mnemonic trace). Indeed, in our minds, we are not able to easily retain more than a small number of “items” at once, which some limit to five, others to seven [13]. The transmission channel of a survey must be unique and not allow for group interviews. The lack of visual interaction then prevents the use of iconographic material, although it can be sent to the respondent in advance. Surveys are generally carried out on large segments of the population; despite this, the reliability of the data depends on the sampling of respondents: in this regard there are noteworthy margins of uncertainty and possibility of bias in the constitution of the sample, which have been reported since the first years in which this procedure began to be used [14].

3 Critical Considerations Regarding the Applicability of Social Research Tools to Capturing Data and Information on Housing Dynamics

The tools described in Sect. 2 of this paper pursue the goal of improving the ability to describe social phenomena: specifically, the question that arises is whether or not they are suitable to be used for the purposes of Research, that is, to capture decisions, desires, and aspirations in meri-to issues related to where to live.

One of the general problems of social research, leaving aside here a consideration of the ethical aspects of studies focused on the individual, is to avoid unwarranted intrusions that can have undesirable effects on the subjects studied with negative repercussions in terms of the validity of the data and information obtained.

The concepts of intrusion and reliability of the data collected, although distinct, are nevertheless interconnected, and the outcome of a social survey, which therefore depends on the reliability of the data and information collected, is affected by the intrusion of the researcher/observer into the activities of the subject under study.

Synthesizing the studies of Galtung [15], a summary table is proposed in which a critical analysis of the different instruments analyzed is advanced, making considerations regarding the risk of producing altered information and data, again in relation to their use in Research (Table 1).

It is therefore appropriate to select techniques that minimize influences, on the part of the researcher, on the observed subject’s behavior or attitudes, which, according to Galtung [15] coincide with nonintrusive techniques, that is, those in which there is no (perceived) intrusion by the researcher into the observed subject’s life and social relationships. These techniques are distinguished from intrusive techniques, where the subjects studied are aware that they are the “object of study,” and where observational findings (information and data) are solicited and produced expressly for the purpose of the research, and thus with knowledge of the observed: in these cases, one can speak of “data construction” by influencing the action but also the mere presence of the researcher the behavior of the observed and its responses.

Table 1. Tools that can be used to capture data and information on housing dynamics

Tools	Intrusiveness level	Recognizable risk of alteration of da-ta/informations	Usability for Reserch Puroposes
Qualitative			
Live observation	Variable	Variable	High
Internet observation	Low/null	Low	High
Discursive interview	High	High	Low
Delphi Method	High	Low	Medium
Focus Group	Medium	Medium	Medium
Documentary and content analysis	Null	Null	Medium
Experiment	Medium/high	Variable	High
Quantitative			
Questionnaire	Medium	Medium	High
Direct interview	Medium/high	Medium	Medium/high
Survey	Medium/high	Medium/low	Medium/low

With specific reference to the survey of settlement needs, particular attention therefore must be focused on capturing information and data that reflect real intentions of the observed and that do not arise from misleading solicitations of the researcher.

In this regard, it appears from early studies on the subject that the understanding of housing phenomena should be done by using different techniques contextually, placing the results in comparison and thereby constructing projections.

With reference to the PRIN research mentioned in para. 1, it is believed that the analysis of housing mobility at the time of digital transition, can be undertaken by combining questionnaires and direct interviews, appropriately structured, with the analysis of data inferred from the web, from which places and areas that arouse interest and appreciation can be inferred, also in terms of residency.

4 Conclusions

The study of approaches, methods, tools and techniques from social research for the capture of preferences, desires, attitudes of individuals is prodromal to the proposition of technologies and assessment tools specifically built to understand the settlement needs of the digital society, in place and future; such knowledge can thus support spatial government processes, even allowing to understand, with reference to the Italian case, the guidelines for a correct sizing of Plans and planning actions (in terms of urban and territorial regeneration), the housing policies to be undertaken, and consequently the necessary legislative/regulatory and procedural correctives. Knowledge of the new settlement needs generated by the digital transition can therefore be a necessary and prodromal resource for territorial government activities, from which urban and territorial regeneration processes can arise precisely responsive to the new flows of housing demand, as well as, consequently, to lay the foundations for fair housing policies. To this end, it is therefore crucial to have adequate knowledge of the techniques that social research has pioneered over time.

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Urban Syntax and Building Semantics in the Process of Quali-Quantitative Signification of the Historic City

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Abstract. This study proposes a methodological and operational model of critical observation of the historic city according to a multi-level approach describing the semiotic nature of a building-urban fabric relevant from the point of view of its existing values and their evolution in the overall progress of the urban context of reference. The elements of this ascending cognitive pathway are articulated in three areas, each characterized by an increasing degree of abstraction: the first consists in the identification of the salient references for critical observation; the second identifies the classes of concrete values that support the semantic reduction; the third consists in the formalization of the relationship between concrete and abstract values in support of the "real estate signification". The case study is the Borgata di Santa Lucia in Syracuse (Italy), of particular interest due to its intermediate location between the well-known Ortigia—the ancient nucleus whose value is increasingly appreciated worldwide—and the new town due its prevalent functional value. The study aims at supporting the formation of the Detailed Urban Plan implementation by providing a structured mapping dynamic databank of the capacities, values and prices.

Keywords: Urban axiology · real estate market fabric · semiotic approach

1 Introduction. Disciplinary Premises for the Role of the Subject

This research is a step of a longer path of the economic-estimative studies aimed at project and plan evaluation. The main contribution that the evaluation science provides to civil society engaged in the reform of living space, is the creation of a shared awareness regarding the soundness of the relationships between different and divergent values, and between these values and market prices. The latter relationship has particular importance in urban contexts characterized by aspects of axiological ambiguity, significant potential for valorization, and administrative uncertainty regarding the process of development of urban transition policies, in some cases conflicting with the preservation of widespread historic and testimonial values.

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This experiment refers to the studies on the “generative strategic planning” [1] of the historic building urban fabrics valorization, on the one hand based on the interaction between different individual axiologies (the preference systems of the stakeholders involved), on the other hand framed within an ethical profile whose general validity is structured within an explicit semantic-syntactic pattern.

The case study is the urban fabric of the “Borgata di Santa Lucia” in Syracuse (Italy) a neighborhood of particular interest due to two complementary circumstances: the first il its intermediate location, between Ortigia—the well-known ancient urban nucleus placed on an islet connected to the mainland by two bridges, whose worldwide architectural, urban and landscape value attracted a huge amount of public and private investment, the latter mainly from outside—and the new city developed in the north since the 1960s, and which performs functions complementary to the cultural, recreational, tourist, and educational ones, the latter related to the presence in Ortigia of a decentralized seat of the University of Catania; the second is the bundle of functional and real estate unexpressed development potential, which has been spreading “by contagion” from Ortigia. The study is part of the research related to the detailed urban planning of which it covers the preliminary stage, i.e. the creation of the information system aimed at supporting the subsequent valuation and programming elaborations for the allotment of the Intervention Categories and the related equalization measures.

The paper proposes a structured system of maps and graphs for a synthetic representation of capacities, values and prices, articulated with reference to 15 Building Types (BTs) to which the categories of intervention and the relative parametric costs can be traced in subsequent extensions and in-depth studies. The paper is in five parts. Section 2 (Materials) briefly describes the study area. Section 3 (Method) explains the three levels of the information-valuation system. Section 4 (Application and results) shows and comments the main findings. Section 5 (Discussions and conclusions) reports the main remarks, potential development and the prospects of this proposal.

2 Materials. The “Borgata Di Santa Lucia” in Syracuse

The “Borgata di Santa Lucia” (Fig. 1), named the “second historic centre” of Syracuse, developed after the demolition of the city walls surrounding the ancient urban nucleus of Ortigia due to its overcrowding and unacceptable living conditions in terms of both housing safety and health. After the development of the valuable “Umbertino” residential neighbourhood over the last two decades of XIX century in the part of the mainland closest to Ortigia, a large area of the north was intended to the Borgata district, which developed between the last decade of XIX century and the middle of the past. The neighbourhood was inhabited mostly by the small and middle class and developed according to a settlement principle with orthogonal street axes. The Borgata covers 76 ha, is home to 8.325 inhabitants and includes 1.825 buildings comprised in 104 blocks. The main public space is Santa Lucia Square in the eastern part, where the Church and Sepulcher of Santa Lucia (1695–1703), and the Catacombs below are located. The building stock has a volume of 1,361,246 c.m; the total dwellings surface area is 427,090, sq.m; the crowding rate is 1.94%, that is 51 sq.m/inhab.

Fig. 1. Territorial framework of Syracuse and urban location of the study area.

3 Method. Concepts and Tools

The objective is to provide an information system for the critical description of the built heritage on a neighborhood scale and at the detail of the Building Unit (BU) coordinating the observation, characterization and evaluation cognitive functions. The theoretical reference of this cognitive process is the linguistic structuralism by F. de Saussure [2]. The basic hypothesis is that each constituent entity of the urban (con)text performs a "sign function" [3, 4]; a sign combines a "signifier" and a "signified" resulting from a signification process. Accordingly, each BU is recognized:

1. At the level of "observation", the cognitive function with the lowest degree of intentional consciousness, addressed to the "distinctions" by the objectual referent category i.e., according constructive, functional, linguistic coherence;
2. at the level of "representation" in the social communication, where the BUs can be compared by cognitive entities (the characteristics) synthesizing in qualitative terms the objectual aspects, thus performing the function of the "signifier";
3. at the level of "evaluation", the signification one, at the highest level of intentional consciousness, by comparing the signifier of the BU, and the "signified/signifier" of comparable properties, thus calculating the parametric prices.

The first and second levels of this axiological approach refers to an information system including 1073 elementary BUs (the information-value bearers) each of which is described and characterized according to the elementary information units framed within the Work Breakdown Structure (WBS) in Fig. 2: the left scheme reports the objectual (mostly quantitative and dimensional) elements; the right one reports the attributes, mostly qualitative, supporting the creation of the "signifiers": urban Location (k_a), Intrinsic (k_i), Technological (k_t), Architectural (k_a) characteristics, scored in a 1 to 5 a-dimensional range by means of appropriate value functions.

The third level of this axiological pattern refers to the 15 Building Types the relationships between concrete ("signifier") and abstract ("signified") information units, respectively, characteristics and property market prices, the latter coming from a real estate market survey carried out basing on a 87 properties sample described according to the above-mentioned characteristics. By grouping the property survey results by building types, the significant prices (quartiles) and variation ranges were provided for each.

Information System Work Breakdown Structure
(first three levels)

	Identification	Block BU
	Location	Address
QUANTITIES	Sizes	Perimeter Site area Gross area Storeys Height Volume Main facade width Further facades width Total exposed area Partial windows area Total windows area

QUALITIES	Location and intended uses (ke)	Accessibility Ground floor intended uses Other floors intended uses GF State of usage UP State of use
	Intrinsic characteristics (ki)	MF Panorama FF Panorama MF Overlook FF Overlook Brightness
	Technology (kt)	Costructive system Fixtures Finishings Maintenance
	Architectural quality (ka)	Building type Age Facade layout Architectural language Roof type Superfetations

Fig. 2. The information content of the first three levels of the WBS.

4 Application and Results

The following synopses outline the multiple referential and axiological profiles of the Borgata reporting the maps and the probability density for each item.

Figure 3 shows the fragmentation degree of the urban fabric measured: (a) by the prevalence of small size BUs characterizing the typical village building landscape (the average BUs site area is 157 sq.m); (b) the average height is 7 m; 308 BUs are single-storey, 475 BUs are two-storey, 207 BUs are three-storey, consistent with the low ratio of the (c) exposed masonry surface; (d) the intended uses of the ground floors denote a functional profile predominantly residential (34% residential, 26% residential service); the tertiary uses prevail along L. Cadorna Avenue and Piave Street; (e) most of the buildings are used (only 77 buildings are abandoned or unused); (f) significant panoramic views mostly characterizes the tallest modern BUs, then the average-low degree is a proxy of the general human-scale dimension of the area.

Figure 4 reports technological and architectural features: (a) the most widespread building types are "basic" (small dwellings for lower classes) (505 BUs) and "minor mansions" (prominent buildings for the middle class) (302 BUs); only 35 BUs are "major mansions" (prominent buildings for the upper class); 232 BUs were replaced or integrated over time; (b) the building stock predominantly dates back to 1900–1970; the 113 BUs of the 1850–1900 period are mostly located in the foundation blocks near Piazza S. Lucia; 287 BUs were built after 1990; (c) one-third of the sample has no, or only a small, part of the façade decoration, one-third has kept most of it, and the remainder keeps the entire original decoration; (d) the roofs types are different and often fragmented: 384 BUs with pitched roofs, 338 mixed, 255 flat, 96 with terrace and canopies; (e) load-bearing masonry buildings prevail (841) in comparison to 151 reinforced concrete buildings; 81

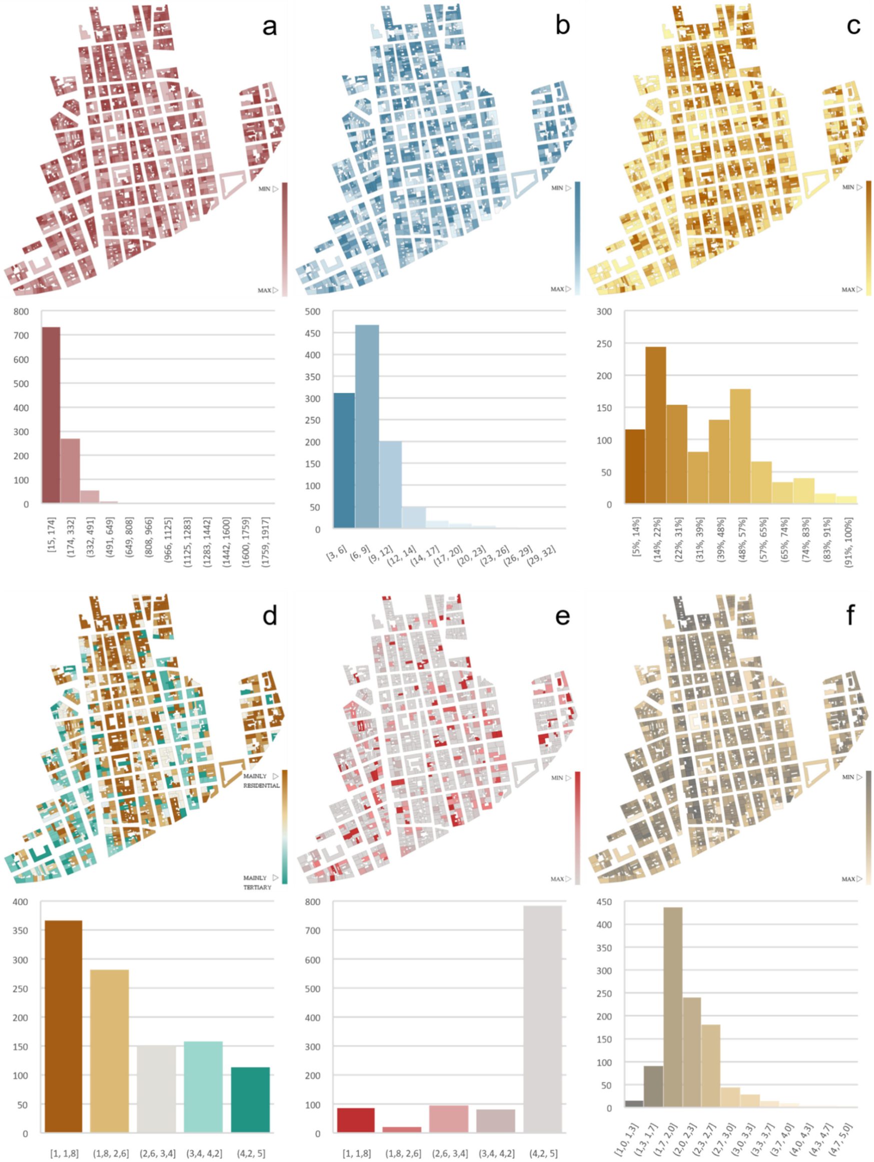


Fig. 3. Reference level synopsis: a) site area: b) height; c) exposed surface of the building envelope; d) uses; e) state of use; f) panoramic views (our elaboration).

masonry BUs have additional storeys in reinforced concrete; (f) the state of maintenance is mostly sufficient: most BUs score above average.

The second stage concerns the definition of the axiological profile of the Borgata. On the basis of a hierarchical expertise-based weighting system, each BU in the sample was synthetically described by four aggregate scores (Fig. 5) relating to location (a), intrinsic

Fig. 4. Reference level synopsis: a) building types; b) age; c) façade layout; d) roof type; d) construction system; state of maintenance (our elaboration).

(b), technological (c) and architectural (d) characteristics. The scores allow multiple comparisons of the BUs and according to the relevance of each characteristic. The further aggregation of them provided the ultimate weighted average score representing the overall value of each BU (e). This valuation is the premise for outlining the following relationships between prices and building types (f).

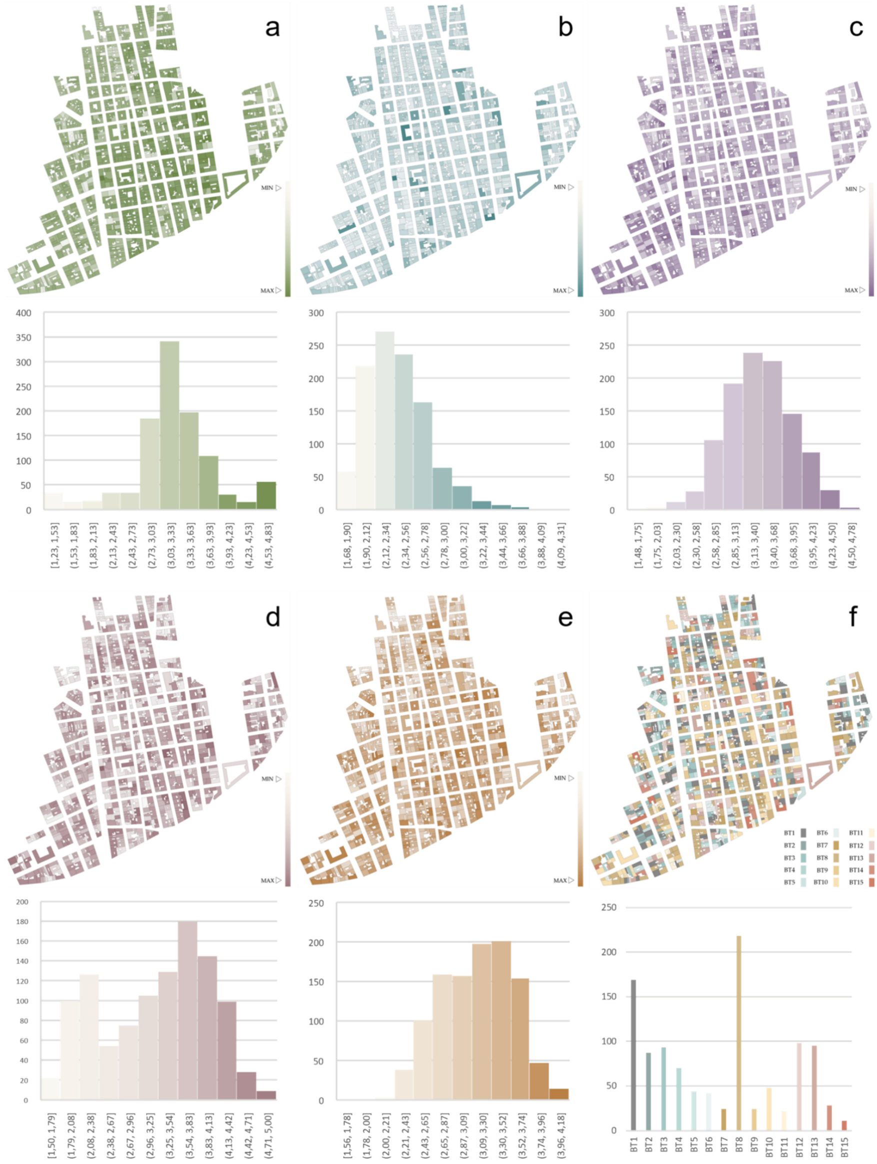


Fig. 5. "Signifier" level synopsis: a) location, b) intrinsic, c) technological, d) architectural characteristics; e) overall score; f) Building Types (BTs) BUs clustering (our elaboration).

The final stage concerns the clustering of the sample by BTs and qualitative value ranges. Figure 6 displays the clustering criteria (top-left table), and the comparison by the significant values (minimum, first, second, third quartiles, and maximum) of the overall aggregate score k^*, , and, in detail, of the four "signifiers" (k_e, k_i, k_t, k_a).

It should be appreciated the greater value of the traditional BTs representing the traditional urban fabrics and the Borgata identity especially as for the architectural quality both the basic building and the minor/major mansions.

The former are characterized by a low technology degree, prospecting potential in the field of renovation and in the prospect of the development of the real estate investments in the segment of the complementary accommodation for students and tourists. Graphs of Fig. 6 support further detail comments.

	Type	N. Floors	Construction Type	Roof
BT1	Basic dwellings	1 Floor	Load b. masonries	Pitched
BT2	Basic dwellings	1 Floor	Load b. masonries	Flat
BT3	Basic dwellings	2 Floors	Load b. masonries	Pitched
BT4	Basic dwellings	2 Floors	Load b. masonries	Flat
BT5	Basic dwellings	3-4 Floors	Load b. masonries	Pitched
BT6	Basic dwellings	3-4 Floors	Load b. masonries	Flat
BT7	Minor Mansions	2 Floors	Load b. masonries	Pitched
BT8	Minor-Major Mansions	2 Floors	Load b. masonries	Pitched
BT9	Minor-Major Mansions	2 Floors	Load b. masonries	Flat
BT10	Minor-Major Mansions	3-4 Floors	Load b. masonries	Pitched
BT11	Minor-Major Mansions	3 Floors	Load b. masonries	Flat
BT12	Contemporary buildings	1-2 Floors	Reinf. Concrete	Flat
BT13	Contemporary buildings	3-4 Floors	Reinf. Concrete	Pitched-Flat
BT14	Contemporary buildings	5-6 Floors	Reinf. Concrete	Pitched-Flat
BT15	Contemporary buildings	7+ Floors	Reinf. Concrete	Pitched-Flat

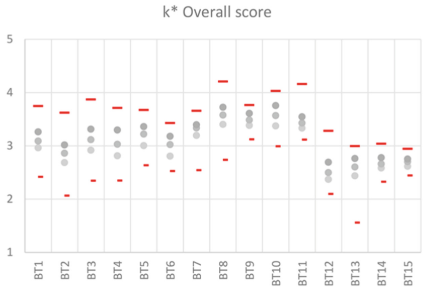


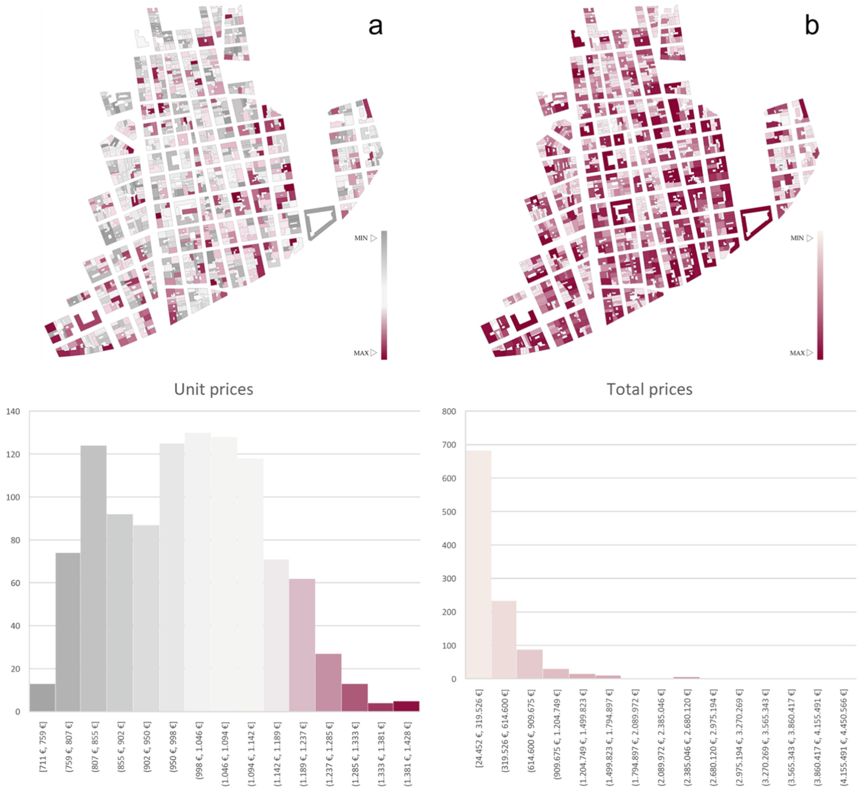
Fig. 6. Comparison of the Building Types by "signifiers" (our elaboration).

The ultimate stage of this urban-building signification path concerns the comparison of the BTs within "the realm of sings", i.e. by "signified" (the prices). Figure 7 shows the mappings and the distribution of the unit (a) and total (b) property values, such as the clustering of the BUs by BTs (columns) and unit price quartile classes (rows).

The unit prices map (a) shows the value of the southern location; the total value map shows the distribution of the real estate capital asset in volume and value.

The distribution graphs show (a) the prevailing of the medium-low to medium quotations, and (b) the fragmentation of the property wealth.

Finally (c), the clustering by BTs and unit price classes shows the placement of a large part of the building stock in the mid-range price, such as the placement of the contemporary buildings in the lowest one.



c

Number of building units by type and price range															Unit prices	
BT 1	BT 2	BT 3	BT 4	BT 5	BT 6	BT 7	BT 8	BT 9	BT 10	BT 11	BT 12	BT 13	BT 14	BT 15	from	to
2	6	2	15	3	8	0	0	0	0	0	73	74	22	7	**711 €**	**855 €**
49	54	46	33	23	25	1	12	2	2	2	23	21	6	4	**855 €**	**998 €**
98	24	40	19	15	9	15	100	15	24	16	2	0	0	0	**998 €**	**1.142 €**
20	3	5	3	3	0	8	89	7	18	3	0	0	0	0	**1.142 €**	**1.285 €**
0	0	0	0	0	0	0	17	0	4	1	0	0	0	0	**1.285 €**	**1.428 €**

Fig. 7. "Signified" level: a) unit property values mapping and distribution; b) total property values mapping and distribution; c) clustering by Building Type and unit price classes.

5 Discussions and Conclusions

Research on the orderly representation of the historic city has long relied on the digital interpretation of the urban ontology, which is based on knowledge formalized through semantic networks in terms of entities, properties and relationships [5–7]. This approach is developed in total continuity with the logic and epistemology of territorial information systems that since long before digitization have supported mostly numerical land representations; among them, since antiquity and for the noble purposes of property taxation, the Land Registries.

In this re-edition, the most recent step in an approach that has been in the process of being updated for a long time now, the sequence of "lexicon", "semantization" and "signification" has outlined new uses for the description of the relationship between signification and typification, necessary for the classification of the existing heritage from the combined viewpoints of architecture and real estate economics, often in conflict [8]. This study shows only the first and part of the second area of the entire horizon of this "generative approach" [9–11] extended through a semantics (practiced here), a syntax and a pragmatics. The area of syntax presides over the formation of redevelopment scenarios; the area of pragmatics represents the reasons for the choice of the most relevant one in a potentially developing dialogical context.

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The URGET VADEMECUM 2030–2050 Project: Applying Threshold Theory to Sustainable Urban Mobility

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Abstract. This paper describes the essential methodological structure of the URGET VADEMECUM 2030–2050 project, funded by the Italian Ministry of University and Research as a Research Project of National Interest (PRIN, Progetto di Ricerca di Interesse Nazionale). It aims to develop an innovative step-by-step assessment methodology to support local policy-making and the allocation of funding in selecting the most efficient and cost-effective measure packages, according to the specific urban context, to achieve European decarbonisation and sustainability targets in Italian cities and towns. It was launched recently, in October 2023, and its methodology is based on the combined use of evaluation and mobility methodologies to provide local administrations with a decision-support tool for the choice of measures and actions. Threshold Theory, Cluster Analysis, and Multi-Criteria Decision Analysis are the three methodologies involved. With the project still at a very early stage, this paper presents its essential methodological outline, focusing on its elements of innovativeness. These reside in the revival and semantic renovation of Threshold Theory: based on the concept of threshold cost, this evaluation methodology allows the interpretation of a phenomenon's subsequent development stages as an irregular process, characterised by static and dynamic thresholds whose passing are associated with threshold cost, which must be spent due to endogenous or exogenous diseconomies. Moreover, the support of Multicriteria Analysis will allow for the determination of the correct weights and parameters to choose from. Cluster Analysis will aggregate continuous results into definite arrays with thresholds at their boundaries.

Keywords: Threshold Theory · Sustainable Mobility · Urban Policies

1 Introduction

The transport sector significantly impacts all three pillars of sustainable development - Environment, Economy, and Social Cohesion - especially within urban and metropolitan contexts. The impacts of transport on the environment essentially derive from its dependence on fossil fuels. The sector is responsible for 23% of global CO2 emissions from

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fuel combustion, 74% due to road transport. The transition to a low- or zero-emission transport is a prerequisite for achieving the Paris Agreement (2016) objective to limit the global temperature increase in this century below 2 °C above pre-industrial levels (if not even lower, to 1.5°). From this perspective, cities will play a key role in concentrating increasing shares of the population and the main activities that generate the demand for mobility. Urban areas use 60–80% of the global energy produced and generate more than 70% of global GHG emissions, inside which transport is a significant source.

The Sustainable and Smart Mobility Strategy, adopted by the EU in 2020, represented a further push toward achieving the goals the European Green Deal set. The goal is to pivot on shifting the current transport paradigm to deliver a 90% reduction in the sector's emissions by 2050. The main action lines of the strategy include the increase of sustainable transport modes and the provision of incentives to drive the transition to sustainable mobility.

In 2024, 4 years later, several urban and national policies and plans have included these aspects. Major examples are Climate Action Plans (CAPs), documents where cities establish their roadmaps for greenhouse gas reduction, including several actions regarding mobilities; Sustainable Urban Mobility Plans (SUMPs) are more specific on this theme and provide operational instructions to "improve the overall quality of life for residents by addressing major challenges related to for example congestion, air/noise pollution, climate change, road safety, and parking" [1]. SUMPs should be drafted by EU local administrations by considering the functional urban area as the scope of action, satisfying residents', visitors', and commuters' mobility needs from a sustainable perspective [2].

The focus on defining place-based actions as cornerstones of the successful implementation of sustainable mobility policies highlights the need to fine-tune measures according to the peculiarities and specific characteristics of places [3]. Besides SUMPSs, an increasing number of local plans report in-depth indications concerning sustainable mobility, such as Sustainable Energy and Climate Action Plans (SECAPs) [4], Sustainable Energy Action Plans (SEAPs) [5], and Climate Action Plans (CAPs) [6]. This proliferation follows the acknowledgement that it is necessary to provide tailor-made actions to support sustainable development; otherwise, introducing unsuitable sustainability measures risks leading to short-lived transformations of urban mobility dynamics. This reflection encompasses most of the widely used solutions in this realm: multimodal hubs [7], electric car recharge stations [8], limited speed areas in urban centres [9], environmental islands [10], and many others.

This is the background for the URGET VADEMECUM 2030–2050 project, an acronym standing for URban de-pollution and de-carbonisation from emissions GEnerated by Transport systems: eVAluation of DEdicated Methodologies, technologies and EConomic thresholds for an Unprecedented Mobility at 2030–2050. The project – funded by the Italian Ministry of University and Research as a Research Project of National Interest (PRIN, *Progetto di Ricerca di Interesse Nazionale*) – aims to develop an innovative step-by-step assessment methodology to support local policy-making and the allocation of funding in the selection of the most efficient and cost-effective measure packages, according to the specific urban context, to achieve European decarbonisation and sustainability targets in Italian cities and towns. In this direction, several European and local projects have focused on developing and collecting solutions for sustainable mobility (especially electric mobility, such as SOLUTIONSplus [11], and transport accessibility, such as HiReach [12]). However, this project is centred on evaluating available and new solutions with a keen eye on their relationship with urban systems. Solutions' effectiveness and optimal applications will be evaluated based on urban characteristics and morphology.

This paper presents its essential methodological outline with the project still at a very early stage. It describes its elements of innovativeness, which gravitate around an evaluation methodology drawn from the field of estimate and evaluation: Threshold Theory. Based on the concept of threshold cost, this evaluation methodology allows interpreting a phenomenon's subsequent development stages as an irregular process, characterised by static and dynamic thresholds whose passing is associated with threshold cost, which must be spent due to endogenous or exogenous diseconomies.

Moreover, the support of Multicriteria Analysis will allow for determining the correct weights and parameters to choose from. Cluster Analysis will aggregate continuous results into definite arrays with thresholds at their boundaries.

2 Materials and Methods

2.1 Threshold Theory

Threshold analysis was first introduced by B. Malisz in Poland in 1961 [13] in urban planning to increase the accuracy of long-term planning in urban development. This theory evaluates the variations in urbanisation costs by linking them to the passing of "thresholds" [14] based on the observation of the existence of physical limitations in cities' development, associated with three main factors: topography, land uses, and infrastructural technology [15]. Several examples can be provided: the cost for the expansion of the water network serving a city increases as the distance of households from the urban connection increases; urban centres are generally built on flat territories with homogeneous height, but elevations might be encountered, thus requiring more onerous infrastructural work or excavations to eliminate slopes.

Besides Poland, where the work has been the object of further development by other authors [16, 17], the Threshold Theory was also imported to Italy by Stanghellini three decades later [18], applied to the Italian context and sporadically elaborated by other Italian authors [19]. An accurate literature review has also detected limited applications in China [20].

The theory distinguishes between "stepped thresholds", "grade thresholds", and "combined thresholds" [21], depending on the form of cost variation. The former threshold is associated with a vertical, single-time increase in total costs: unitary costs, intended as costs related to the increase of units, do not directly increase, while an additional fee must be sustained to overcome a physical issue; for example, the construction of bridges or viaducts over rivers or valleys in motorway or railway networks is the case.

Instead, grade thresholds indicate a point after which an increase in unitary costs occurs, leading to a progressive increase in total costs over the following development; one example is a soil characterisation where soils located further from the city centre have lower stability, thus requiring more burdensome foundation works for household construction.

Finally, combined thresholds include both forms of cost increase: this occurs when building new secondary urbanisation works, i.e., public buildings, which first require a single-time cost for construction and then increased management costs for all inhabitants (Fig. 1).

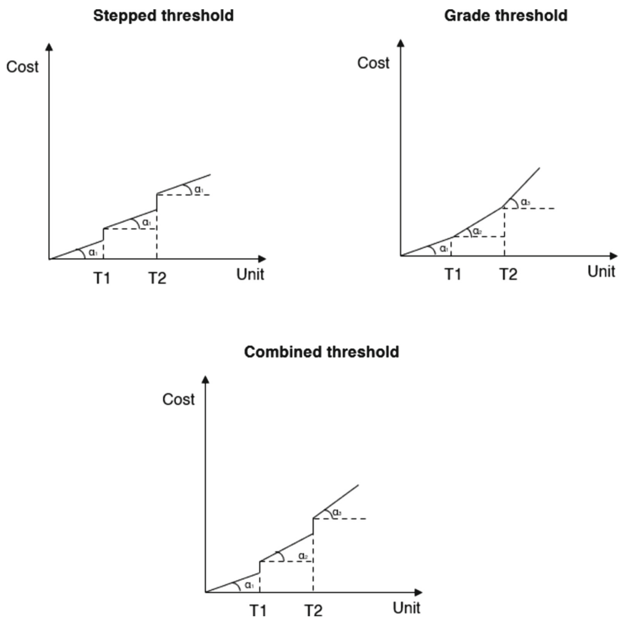

Fig. 1. Graphical representation of the three threshold typologies, as indicated by the titles above the respective graphs.

2.2 Cluster Analysis

In the realm of mobility, cluster analysis is particularly useful for various purposes: among the main ones is the possibility to group individual flows (pedestrian or vehicular flows) to determine mobility demand and travel patterns [22], therefore evaluating micro-mobility [23], quality of life according to the demand's state of satisfaction [24], the use of soft mobility [25], and more.

Besides this, Cluster Analysis – supported by unsupervised machine learning [26] – is used in countless research fields as a general tool to automatically define classifications within a heterogeneous set of elements based on data similarity. This has also produced novel application modalities of this method in mobility: some examples include the classification of travellers' driving style [27] or the evaluation of street safety related to weather [28].

2.3 Multicriteria Decision Analysis (MCDA)

Multi-criteria Decision Analysis methods have often been used to model and resolve several real-world problems [29], especially recently [30]. Mobility, in particular, has been the subject of numerous MCDA-based studies to evaluate different scenarios and specific conditions for overall analyses [31] or particular aspects, such as the collocation of a new facility [32].

The methods chosen within the family of MCDAs are remarkably heterogeneous: Q-Rung Orthopair [33], Fermatean Fuzzy [34], TOPSIS [35], Aczel Alsina [36], and GIS-based ones [37]. The specific decisions on which the methods are adopted and developed include the purchase of electric vehicles [38], green fuel alternatives [39], the selection of waste collection trucks [40], and many more.

3 Project Methodology

The project's methodology is based on three phases:

- inventory of sustainable mobility solutions and benchmarking analysis;
- threshold values identification through Threshold Theory and Cluster Analysis;
- best alternative selection with a combination of Threshold Theory and Multi-Criteria Decision Analysis.

3.1 Inventory of Sustainable Mobility Solutions

The measure packages evaluated in the project's methodology and aggregated in its inventory will be extracted from local and national plans and policies that are compliant with the Italian context. Sources include local mobility plans, specifically focusing on SUMPs and remarkable pilot projects launched in them, and broader sustainability-related plans like SECAPs. Collected actions will involve:

- reducing the dependency on transport to meet people's everyday needs (work, education, healthcare, shopping, leisure, etc.);
- reducing the strong dependence on private motorised transport for travelling within the urban/metropolitan area by promoting the shift to soft mobility (walking and cycling, guaranteeing safety);
- reducing the dependency on crude oil for the propulsion of transport systems;
- mitigate/compensate for the local pollution and GHG emissions generated by transport systems, including residual non-compressible emissions, with care to literature from public health (e.g., lung diseases by PM 2.5/10).

The selection of feasible measures will naturally depend on the structural features of the site, among which morphological features (i.e., size, form, and structure of the urban area) and land-use-related parameters (e.g., population, density, and distribution of land uses) are those that most affect mobility. There is empirical and scientific evidence that low-density dispersed urban patterns and rigid land-use zoning generate car dependency, higher energy consumption, and emissions from transport. In contrast, compact mixed-use urban patterns are more likely to both reduce people's dependence on transport for their daily needs and encourage sustainable mobility. By further developing GIS-based applications, spatial thresholds will be derived from the analysis of both physical (e.g. road widths) and accessibility parameters (e.g. network distances from urban attractors) that condition the use of transport infrastructure.

3.2 Threshold Theory's Original Application

As stated above, the URGET VADEMECUM 2030–2050 project's core is the Threshold Theory. As shown above, in the literature review, the Threshold Theory has had a limited fortune outside Poland, except for Stanghellini's import; however, it was abandoned.

Its merit resides in relating the increase of costs over time to context characteristics, intending them as an intrinsic characteristic of urban development and actions; despite occurring at future stages, they should be modelled at the beginning of urban modelled as they must be considered during planning to evaluate all available options and their convenience correctly.

However, despite the validity and fruitfulness of this intuition, compared to the age in which the method was conceived, several data-based predictive tools for urban planning, including statistical analyses, have flooded the scientific literature, allowing for more accurate and expedited evaluations of future urban states [41]. This has left less room for using more economic-based tools like the Threshold Theory. In this research project, the current formulation of the Threshold Theory will be dramatically expanded, reaching other scopes beyond the time dimension. These include:

- the demographic and urban thresholds associated with the use of soft mobility (population density, age, family type, built fabric density);
- the infrastructural thresholds associated with the use of public transport (mean distance between bus and metro stops, mean waiting time when using public transport);
- the infrastructural and socio-economic thresholds associated with the electric transition (GDP per capita, local vehicle fleet).

In other words, in Threshold Theory, a stepped threshold T_1 can be modelled as:

$$Q < T_1 \Rightarrow C_{tot} = Q \cdot C_u \tag{1}$$

$$Q \geq T_1 \Rightarrow C_{tot} = Q \cdot C_u + C_{T1} \tag{2}$$

Q is the number of units, C_u is the unit cost, and C_{T1} is the single-time cost associated with the stepped threshold T_1. In the applications of Threshold Theory exemplified above, the relation between population's age in a neighbourhood and the use of soft mobility could be modelled as follows:

$$A < T_2 \Rightarrow U_{tot} = N \cdot U_{\%} \tag{3}$$

$$A \geq T_2 \Rightarrow U_{tot} = N \cdot U_{\%} - U_{T2(\%)} \tag{4}$$

In Eqs. (3) and (4), A represents the mean age within the considered neighbourhood, T_2 is the hypothesised age-related threshold for the use of soft mobility, U_{tot} is the total number of soft mobility users in the neighbourhood, N is the number of residents, $U_{\%}$ is the average percentage number of soft mobility users in the broader territorial context, and $U_{T2(\%)}$ is the percentage reduction in the number of users due to passing the age threshold T_2.

Thus, the Threshold Theory can allow the interpretation of urban contexts' intrinsic characteristics by applying a combination of thresholds to mean values, elaborating on statistical data from observatories and the scientific literature.

This multi-dimensional yet static application will be complemented by the method's original dynamic vocation: that is, the positive results of the measures, such as an increase in the use of soft mobility and public transport or the reduction in the duration of an itinerary, will be considered in a long-term perspective, by studying how the intrinsic conditions of the urban scene may lead to a future decrease in the desired performance (as a counterpart to the unitary cost increase in the original theory).

3.3 Role of Cluster Analysis and MCDA

The traditional purpose of Cluster Analysis in the field of mobility will be one of the main tools used to analyse urban contexts, their mobility demand, and trends, as already detailed in the literature review above. Moreover, this methodological framework will be used to organise the significant amount of data available concerning the factors and the statistical relationships that determine the convenience of choices in the realm of measures and options for sustainable mobility. Instead of continuous data, this methodology will allow the construction of homogeneous clusters, identifying different urban "states" characterised by different suitability to introduce measures.

This apparent simplification benefits the representation and the explicitness of urban analyses, whose characteristics can be classified into threshold conditions (arrays), facilitating the repeatability of analyses and decisions.

After determining each measure's effectiveness and long-term cost, MCDAs will be used to decide between the available alternatives. More specifically, MCDA will require identifying the objectives and their corresponding attributes or indicators, by scoring, ranking and weighing a wide range of qualitative impact categories and criteria, which usually are not considered. MCDA will be organised into the following phases:

- selection of the alternative sustainable mobility scenarios (resulting from thresholds analysis);
- definition of judgment criteria;
- analysis of the impacts on the alternative mobility scenarios;
- assessment of the actions' impacts on each selected criterion;
- aggregation of judgments;
- choice of the preferred/optimal sustainable mobility scenario(s).

4 Conclusions and Future Developments

The main objective of the URGET VADEMECUM 2030–50 project is to tackle local pollution and global neutrality issues in the urban context regarding mobility and related transport systems in the short, medium, and long term.

The proposed methodology is based on quantitative and qualitative data, new technological solutions, and the combination of different evaluation tools, which are reinterpreted in an up-to-date way. There are many levers to make urban mobility more sustainable, even though they are not always well known. They may deal with the functioning and organisation of both cities and transport (for passengers and freight), a wide range of policy interventions (e.g. concerning new powertrains and Intelligent Transport Systems/ITS), as well as the development of green solutions (e.g. concerning traffic lights' control, geo-fencing for hybrid powertrains and battery-electric vehicles, aggregation processes for mobility flows, etc.).

Among these measures, priority can be given to those that promote alternative transport modes to low-occupancy private cars, including soft- and micro-mobility, public transport, shared mobility, pooling services and advanced Mobility-as-a-Service solutions (MaaS).

However, the real chance to achieve climate neutrality is strictly linked to the implementation of overall and combined strategies shared among different actors.

The innovative methodology proposed for this project will support decision-making and fundraising by selecting and calibrating different measures and policies aimed at reducing/eliminating climate and pollution impacts from urban mobility, considering the spatial and land-use variables of Italian urban settlements.

The project has just recently started (October 2023), and methodological experimentations and developments are still underway. However, the innovative framework, based on achieving a shared structure of thresholds where heterogeneous quantified parameters coexist under the Threshold Theory, can represent a turning point for the capillary diffusion of tailor-made solutions in urban sustainability through an easily readable and interpretable evaluation process.

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Metropolis of the Second Modernity in the Ecological Age: Crafting a Sustainable Future

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Abstract. This interdisciplinary investigation envisions a sustainable future for the Second Modernity Metropolis, with Metropolitan Heritage taking centre stage as a pivotal transformative design tool. Anchoring city knowledge in lessons from the past, this approach aims to shape a resilient, inclusive, and sustainable metropolitan future through collaborative efforts such as those of the Heritopolis Society, an UN-Habitat Initiative.

Delving into the Metropolis DNA, the study navigates the interplay between anthropocentrism and a non-anthropocentric perspective, guided by the concept of *Entanglement* between Nature and Culture. Additionally, Metropolitan Landscapes undergo a redefinition, harmonizing nature and culture through a methodological mapping tool named Metropolitan Cartography, which systematically represents metropolitan scales to foster comprehensive urban sustainability.

A cultural revolution within metropolitan governance emerges, leading to a novel identity grounded in sustainability. This recognizes the crucial role of Metropolitan Heritage in fostering resilience through new design and anthropological practices, intertwining tangible and intangible aspects. Moreover, the active involvement of academia must educate agents capable of navigating technological innovation cycles and fostering convergence between macro and micro scales.

Sustainable Urban Metabolism underscores the importance of low-impact processes, contributing to crafting the Metropolis of Tomorrow through innovative and coordinated strategies aligned with the Sustainable Development Goals (SDGs). The concept of the Second Modernity Metropolis in the Ecological Era emphasizes *anti-fragility*, envisioning the metropolis as a *bioregion*. Four theses explore Human-Nature co-evolution, the role of nature in shaping human-technology relationships, fostering green linkages, and reimagining the metropolis from an anthropological perspective.

Keywords: Metropolitan heritage · Anti-fragility · Nature-human-technology relationship · Hotspot network · Entanglement

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1 Unveiling Metropolitan Heritage as a Design Tool

1.1 Metropolitan Heritage: Shaping a Sustainable Future in the Second Modernity Metropolis' Ecological Age

How will the Metropolis of the Second Modernity evolve in the Ecological Age? This question sets the stage for our exploration of the transformative potential of Metropolitan Heritage. Through an interdisciplinary approach, we blend anthropological perspectives, innovative design tools, and integrated policies to imagine a resilient, inclusive, and sustainable metropolitan future.

Metropolitan Heritage offers a compelling solution today and promises sustainability in the long term. We focus on the future by harnessing this heritage as a design tool, recognizing that past knowledge can inform future prosperity. Understanding the significance of Metropolitan Heritage as a tool for designing sustainability, we acknowledge that learning from past practices can shape a sustainable path forward.

The Heritopolis Society [1], in partnership with the UN-Habitat and the Korean Culture Minister, spearheads discussions on leveraging metropolitan culture and legacy to improve the well-being and health of metropolitan residents.

Furthermore, the metropolis serves as a hub where a culture's creativity flourishes and where the importance of public welfare is consolidated. While the finished cities of the past may have been considered artefacts to be preserved, today's metropolises consist of layers that reveal their dynamic DNA. This understanding prompts us to focus on preserving, developing, and transforming processes rather than static objects. What attributes of a metropolis set it apart from previous urban dimensions become crucial for consideration?

2 The Metropolis DNA: Unravelling the Layers of Urbanity

2.1 DNA as Cultural Transmission

Several authors have introduced the concept of DNA in urban studies. Lynch [2], for instance, refers to it as characteristic elements or functions that define the essence of a city. He uses an electrical metaphor to explain that not all functions are uniformly distributed across the city, which can lead to imbalances. Designing a high-quality urban environment involves incorporating all these characteristic elements in varying quantities. The notion of potential is also linked to the modern idea of the membrane, particularly in contemporary public spaces. These spaces are understood as polygons composed of functional epicentres, allowing for a diffuse centrality that reshapes our understanding of public spaces and their boundaries. In these focal points, as Lynch suggests, projects must aim to establish a strong civic identity.

P.b.Ortiz [3] introduced the concept of the Metropolis Genome, which integrates a metropolis' economic, social, physical, and governance components into one cohesive system. This genome orchestrates the alignment of these components, along with their respective factors and subfactors.

However, there is a question about whether the DNA metaphor should solely depict a linear transmission of information or if it can also illustrate how culture is passed down from generation to generation through tangible and intangible heritage. At a higher level, we are revisiting the essence of communication; it is not merely about transmitting information but also about understanding and assimilating what is needed from others. This becomes especially relevant in the contemporary era, where we face complex challenges of intergenerational dynamics.

3 The Metropolitan Landscapes: Balancing Nature and Culture

3.1 Milanese School's Landscape Perspective

The Milanese School's Landscape Perspective [4] has significantly influenced urban planning since the 1960s, notably by replacing the term "History" with "Environment." This shift in terminology reflects a broader understanding of the metropolitan region as a complex compilation of various landscapes, including natural, rural, rurban, and urban areas.

A key challenge in this perspective lies in managing the transitional phases between these diverse landscapes, often leading to hybrid environments or *collisive sites* [5]. These transitional zones require careful re-evaluation and reconceptualisation to address the complexities that emerge during shifts from one landscape tone to another.

Furthermore, the concept of Landscape Urbanism has played a significant role in transforming the traditional understanding of the environment in Latin culture into the Anglo-Saxon notion of landscape. This reinterpretation often focuses on the ecosystem services of supply, regulation, and culture [6]. However, questions arise regarding whether culture can always be interpreted as a 'service' on par with the other two.

4 Approaching Sustainable Urban Metabolism in Metropolitan Disciplines

4.1 Metropolitan Cartography Tool: Navigating Uncertainty and Shaping Sustainable Futures in the Second Modernity

In the Ecological Age, the introduction of the concept of the bioregion [7] offers a potential solution to this issue, since the concept of the metropolis as a bioregion presents a new perspective where nature and culture intertwine in unconventional ways. By transcending administrative boundaries and allowing for the calculation of ecological footprints, the bioregion concept helps determine the extent of the metropolis's impact on the surrounding territory. This insight is crucial for understanding how metropolitan regions consume land beyond their immediate limits and highlights the importance of past sustainable land management practices.

This fact challenges traditional categories and emphasizes the need for the Second Modernity Metropolis to adopt a paradigm of anti-fragility and de-risking [8]. Specifically, it must address the dynamic, emergent structures and relationships that characterize contemporary urban environments.

To achieve sustainability in spatial planning, the Second Modernity Metropolis must prioritize environmentally low-impact processes across various domains such as anthropology, society, technology, economics, and management. This includes managing energy, materials, and land consumption within a metabolic framework and recognizing the ecological implications of these activities. The rapid urbanization associated with metropolitanization has significantly transformed local lifestyles, marking a generational shift.

The transition to the Second Modern Metropolis introduces a notable element of uncertainty compared to the stability of the past. This uncertainty is a defining feature of contemporary urban environments, especially as various factors converge to create diverse and sometimes alienating urban scenarios.

To effectively navigate the complexity of metropolitan landscapes, the Metropolitan Cartography tool [9] (Fig. 1) systematically represents the metropolitan scale and the dynamic interplay between nature and culture. It offers guidelines, tools, and implementation strategies aligned with the New Urban Agenda (NUA) and Sustainable Development Goals (SDGs), facilitating localized efforts for sustainable development initiatives.

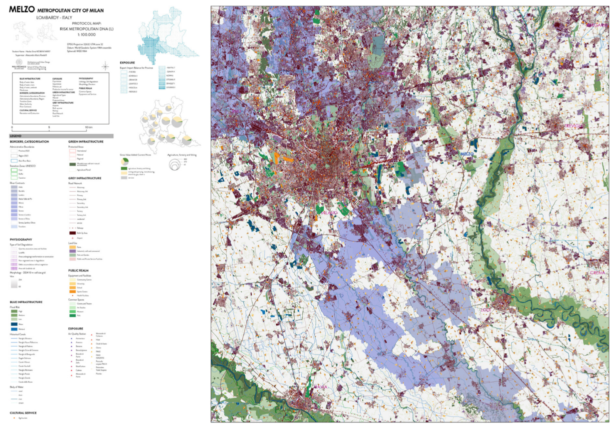

Fig. 1. RiskDNA. Credit. Hasibe Simal Keskin, 2023

Metropolitan Cartography serves as the means to address the intricacies of metropolitan quality closely linked with the multifaceted functions within its metropolitan landscapes' connectivity. In the metropolitan vision, metropolitan connectivity refers to the average connections between the elements of the spatial structure of the landscapes and the morphology of the metropolitan territory. Connectivity is a property of the bioregion that describes the degree of connectedness of the morphology of the metropolis [10] concerning the principle of green-green infrastructure continuity [11]. These connections can be described by mapping.

The investigation of connectivity through Metropolitan Cartography Maps would allow us to understand the morphological structure of the green, grey, and blue infrastructures of the territory. This would allow to convert the urban-rural margins (those lacking environmental and architectural quality) into potential sites for the reactivation of metropolitan flows of cultural, natural, and anthropic services.

This comprehensive tool compares various cultural, geographical, and operational scopes, to establish a shared vocabulary and common understanding through interdisciplinary translation. It encompasses subjects related to urban sustainability, including anthropology, sociology, architecture, planning, economics, and energy. This adaptable approach is crucial for responding to the contemporary age's rapid transformations.

Additionally, we will outline guidelines for developing new assessment instruments to portray the current state and potential projections of metropolitan landscapes. These may include Protocols maps and maps of Dynamics, storyboard schemas, and sustainability indicators [12]. Importantly, we will establish a system of actions directed at governance choices, engaging citizens in comprehending, recognizing, and endorsing alternative transformation, substitution, and maintenance strategies within the life cycle of their city and territory.

5 Integrating Inter-Scale Design, Cultural Fusion, and Economic Considerations for a Sustainable Future Through Anthropo-Ecological Perspectives on Natural and Cultural Paradigms

5.1 First Thesis. Nature and Metropolis. Metropolitan Architecture Project as Collective Landscapes Futures

Historically, natural landmarks like volcanoes, hot springs, and mountains held deep cultural significance, symbolizing a shared reality ingrained in collective memory. However, the Anthropocene Age has brought an epistemological crisis, challenging traditional notions of nature and human influence. Landscape Urbanism, Metropolitan Architecture and Metropolitan Cartography [13] emerge as essential disciplines and tools for constructing hospitable cities, striving to strike a delicate equilibrium between the environment's life cycle and human consumption. Metropolitan Architecture Project (Fig. 2) aims to create a unified temporal space using technology that can be experienced within the physical locations of the new metropolis. It establishes a continuum between interconnected scales by employing recognizable physical cues, bridging historical and contemporary locations, networks, and landscapes—both natural and cultivated. This architectural initiative at the metropolitan scale dictates the transition across various scales, seamlessly integrating urban, rurban, rural, and natural elements through innovative introductions such as novel built form types and inventive land-use patterns. The metropolis, characterized by multipolarity, witnesses the emergence of a new metropolitan centrality extending into the surrounding territory, harmonizing built and natural landscapes and navigating the juxtaposition of wet and dry environments [14]. This transformative shift towards a sustainable and antifragile metropolis [8] is essential for preserving the environment and fostering reconciliation with the forces of urbanization.

5.2 Second Thesis. Nature and Metropolis. The Crucial Role of Nature in Shaping the Relationship Between Humans and Technology

The role of nature is fundamental in shaping the intricate relationship between humans and technology. As we strive for a more collaborative connection with nature, it is crucial

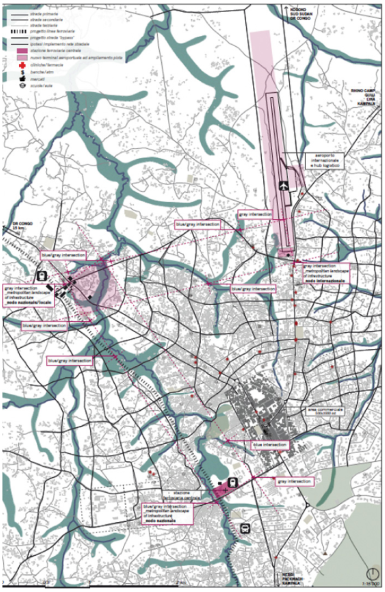

Fig. 2. Arua, Uganda, Linkage Urban-Rural. Credit Bianca Cesarotti, 2023

to design technology to align with the inherent principles of the natural world. Culture is the guiding force that blends technology and nature into a cohesive entity, providing a framework for understanding the complex relationship among humans, nature, and the "culture of nature," particularly in agriculture. In the context of implementing the twin transition green and grey (embracing a new urban-rural pattern), the meticulous actions of the Metropolitan Architecture Project introduce a range of scales and landscapes. These actions facilitate regenerative agriculture and ensure its sustainable integration, marking a significant step towards fostering a harmonious coexistence between urban and rural realms.

The Metropolitan Architecture Project (Fig. 3) also embodies a collective temporal experience shared by a diverse group of individuals who, despite physical distances, feel a sense of unity through technology. This innovative concept prompts a fundamental exploration into creating a shared metropolitan temporal space facilitated by technology, now realized in the new metropolis through distinct physical locations characterized by innovative built-form types.

5.3 Third Thesis. Nature and Metropolis: Fostering Sustainable Green Linkages in Metropolitan Areas Through Integrated Policies and Adaptive Management

Recognizing the metropolitan landscapes as a *bioregion* [15] signifies a paradigm shift in approaching the metropolis. It draws from systems theory and adaptive management principles that underscore the importance of understanding the underlying causes and drivers of territorial processes intricately tied to the natural structure of the land. The

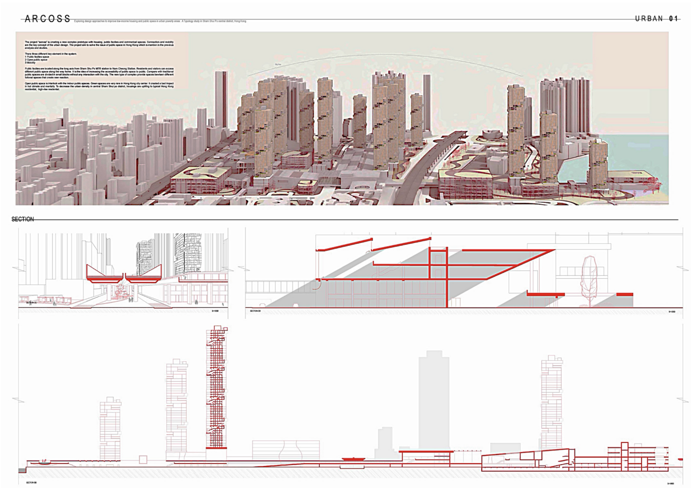

Fig. 3. A Typology study in Sham Shui Po central district. Credit Lai Cheuk Sze, 2023

evolving metropolis models must pivot around acknowledging the *bioregion*, intertwining urban centres with the territories they inhabit. Initiating an anthropo-eco transition becomes imperative to reimagine our metropolises, grounded in a systems theory and complexity paradigm [16].

We evoke a metropolitan anthropology shaped on the ecology processes knowledge implementing new practices, solutions and policies that facilitate sustainable connections across various metropolitan sectors—such as water, agriculture, food, and transportation—is vital to mitigate adverse socioeconomic impacts and introduce corrective measures addressing prevailing inequities. These integrated sectors are pivotal in addressing the urban-rural linkages outlined in the New Urban Agenda.

Pursuing of the Sustainable Development Goals, specifically focusing on Goal 11 [17], expanding the adoption and implementation of integrated policies and plans by cities and human settlements is crucial. These policies and plans should champion inclusivity, resource efficiency, climate change mitigation and adaptation, and disaster resilience [18]. Concurrently, comprehensive disaster risk management strategies should be developed and implemented at all levels in line with the Sendai Framework for Disaster Risk Reduction 2015–2030 [19]. The emphasis on integrated policies and plans resonates in the European Union's recovery and resilience mechanism, aligning with the European Green Pact and the Digital Agenda [20], supporting the transition toward a green, digital, and resilient economy.

Considering ecosystems as complex hierarchical systems, the metropolis ecosystem includes distinct subsystems—metabolic, functional-sensory, and immunological-identity subsystems—demanding equilibrium from a functional geography perspective. The Territorial Heritage System, encompassing green infrastructure, blue infrastructure, and agricultural spaces, proves indispensable in maintaining a region's character amidst external pressures. This subsystem's intricate dynamics warrant study across interconnected spatial and temporal scales.

5.4 Fourth Thesis and Conclusion. Reimagining the Metropolis, the Twin Transition

Addressing territorial and urban inequality is paramount for sustainable development, necessitating interventions to rebalance disparities and foster inclusivity. At the metropolitan scale, integrating culture, nature, and the biosphere is essential for enhancing the quality of life and creating resilient communities. As a multidisciplinary mapping methodology, our metropolitan cartography is needed to understand complex territorial contexts and address specific needs within interconnected systems, including mobility systems and flows.

The ongoing technological acceleration occurring within a neoliberal framework, signifies the ability to collect, process, and utilise vast amounts of data. While this presents opportunities to enhance human capabilities, it challenges decision-making processes and cultural divides between digital and traditional realms. Achieving balance requires concentrating decisions or adopting a democratic approach with accessible information for public debate and decision-making [21].

In metropolitan planning, understanding the dynamic relationship between humans and nature requires an anthropological viewpoint emphasising inclusivity and resilience. Policymakers must investigate intersections between digital and green transitions and inequalities, focusing on leveraging digital technology, preserving cultural heritage, and equipping vulnerable populations with relevant skills. Additionally, promoting relocalization, strengthening local autonomies, and emphasizing care and compassion are crucial for building resilient communities in the face of rapid technological advancements and environmental challenges.

Innovative approaches such as Metropolitan Urban-Rural Linkages (MetroURLs) [22] offer a holistic framework for addressing anthropo-ecological problems by incorporating Nature-Based Solutions (NBS) and Culture-Based Solutions (CBS). NBS play a vital role in decarbonization, hydrogeological rebalancing, and climate change adaptation, aligning with the goals of ecological transitions and One Health [23]. CBS contributes to meeting diverse societal needs and fostering sustainable development by integrating science, nature, and culture.

The geo-historical DNA produces the geographic footholds capable of generating innovation in a new inventive system [24] dealing with the Metro Urban-Rural Linkages context that we consider metropolitan landscapes 'buffer zones and resources for innovation activated by the Metropolitan Architecture Project of the physical space. Moreover, as finance for adaptation is mainly allocated to national governments, there is a need to involve subnational governments at the metropolitan level within the private sector [25] to consider systemic and systematic adaptation measures that tailor climate financing to the needs of local communities.

Suppose the metropolis is a system of places and is the network city. In that case, we aim to explore the potential of the antifragility approach to help institutions and policymakers at different levels to consider the conditions under which their actions and decisions can help people and places to develop attitudes and characteristics not only to resist but also to "ameliorate" aftershocks [8].

Our method comprehends three first operations: study MetroURLs as metro-buffer zones in the design process to activate resources and create an inventive system; interpret and represent MetroURLs as buffer zones to develop a narrative of environmental knowledge [26] and environmental governance; build an abacus of patterns that can be identified as the URLs context into the structural plan to recognise information levels towards open-source data.

Next, we want to develop the idea of *preventive armatures* and study Metro-URLs as buffer zones in the design process, dealing with a strategy operating in hotspots to define a settlement model to lead the process of activating resources and creating an inventive system (Fig. 4).

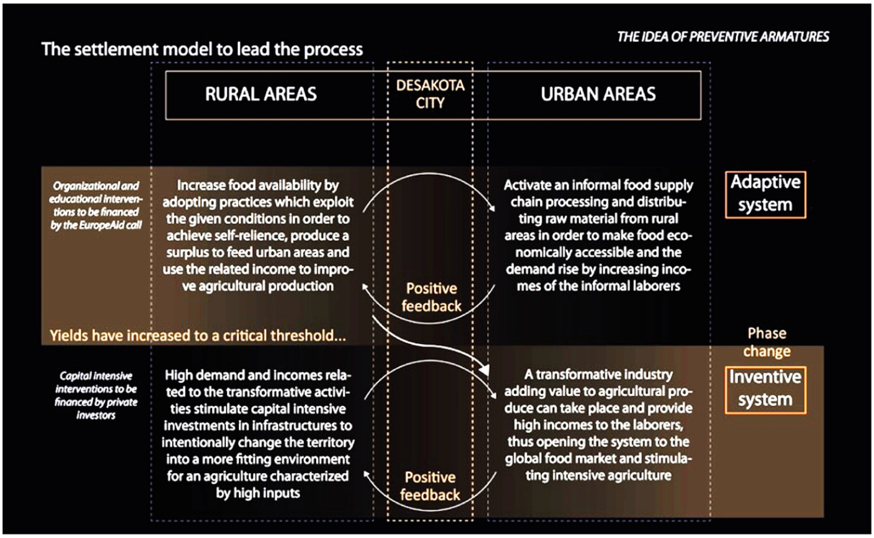

Fig. 4. The settlement model to lead the process of preventive armatures definition, MSLab, A.Zammataro

Lastly, we foster the construction of MetroULRs pattern through a hotspots network system [27] that addresses water, waste, and energy challenges, promoting sustainable urban and environmental strategies for food sovereignty and food security that foster the One Health strategy [23]. The hotspot network (Fig. 5) is a settlement stem cell that functions in different contextual situations and allows different insertion forms in urban and rural peripheral contexts.

Conclusively, our hypothesis suggests that Metropolitan Urban-Rural Linkages, by incorporating the NBS, transmute into the new collective sustainability heritage, offering a holistic approach to simultaneously address multiple anthropo-ecological problems. The biological aspect complements the concept of anti-fragility since the NBS refers to the stabilizing culture that is the primary function of the metropolis. Its counterpart, the CBS, represents the social aspect in the cultural or humanistic sense and not only technical, considering the social issue in the sense that it is related to custom and behaviour and, therefore, cultural. NBS are essential for decarbonisation, hydrogeological rebalancing, and climate change adaptation, aligning with the goals of ONE HEALTH and ecological transitions. Nevertheless, a crucial aspect is the role of NBS in shaping Culture-Based Solutions (CBS), integrating science, nature, and culture to meet diverse societal needs.

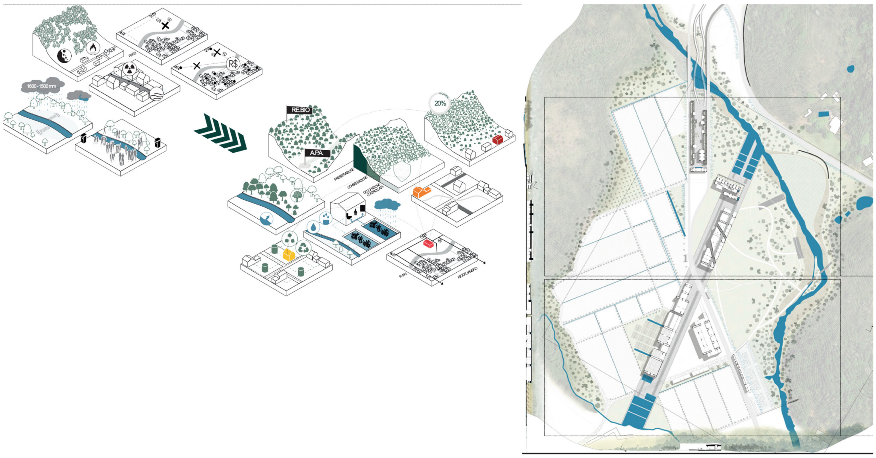

Fig. 5. The Hotspot Multifunctional Pattern,Rio De Janeiro Tinguà Valley MSLab, C.Buzzella, B.Tomasella

The prevailing anthropocentric worldview views the globe as a resource for exploitation, contrasting with the Earth's nature of interdependence and connection [28]. Coexisting within two entwined worlds—the globe and the planet—with distinct temporal logics, one anthropocentric and the other non-anthropocentric, reveals the intricacies of our current epoch, the Anthropocene. In this era, human actions significantly impact the Earth system, necessitating a revaluation of our relationship with nature.

The concept of co-evolution between nature and humans faces multifaceted challenges. Foucault [29] argued that altering the fundamental rules of nature is beyond human capacity. At the same time, [30] emphasised the role of cultural models and social relations in shaping human perceptions of what is natural. Contin [11] introduced the notion of catastrophic discontinuity while preserving tradition, allowing room for human capabilities and social action.

In our discourse, Metropolitan Architecture Projects integrate Nature and Culture through green-grey infrastructure and MetroURLs patterns as a new land use strategy, aiming to create liveable cities by redefining new urban morphotypes. They seamlessly blend old and new architectural forms, urban spaces, and landscapes. This endeavour establishes a gradient between interconnected scales through discernible physical markers. It introduces innovative land-use and built-form types [13], including regenerative agriculture and utilising digital and physical network solutions.

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Enhancing the Anglona Coros Territory: A Tourist Itinerary Design and Evaluation Process

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Abstract. Sustainable and cultural tourism challenges today cannot fail to deal with the objectives of the ONU Agenda 2030. Furthermore, in many European regions sustainable and cultural tourist strategies and activities frequently extend into territories where marginalization, progressive depopulation and abandonment processes represent critical dynamics. This article focuses the Italian framework by analyzing two items: 1) the fragile contexts and the link with the characteristics of tourist attractiveness, attempting to go beyond the current interpretations and positions; 2) the scientific debates on the themes of sustainable and cultural tourism as triggers for territorial valorization. The article proposes a methodological approach aimed to support local authorities in designing tourist itineraries by taking into account the stakeholders' preferences through a Conjoint Analysis model and by evaluating the territorial potential by means of spatial analyses based on cross-dimensional indexes and indicators. In particular, this article aims to reflect on the future of the Anglona Coros inner and fragile territory in the Sardinia Region (Italy) as a potential area of tourism development. With these multiple perspectives, the conditions of marginality and fragility are analyzed and the proposed methodological approach is applied in order to outline a new tourist itinerary able to activate a dialogue with the local Public Administrations and with all the stakeholders who have already shown interest in fostering a decision-making process and developing new local tourist strategies.

Keywords: Sustainable Tourism · Economic Evaluation · Fragile Territories

1 Introduction

Sustainable and cultural tourism challenges today cannot fail to deal with the objectives of the ONU Agenda 2030 [1, 2], with the specific conventions and resolutions of the Council of Europe [3], with the program on European cultural routes and the policies of ICOMOS, which recently revised the "ICOMOS International Charter for Cultural Heritage Tourism" [4], underlining how essential is "Reinforcing cultural heritage protection and community resilience through responsible and sustainable tourism management" [5]. As Mzembe et al. [6] emphasize, there are two core issues: 1) the educational and responsible vision of tourism emerges as a pivotal response to the heightened awareness among

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travelers regarding heritage and territories, recognized not merely as physical spaces but as repositories of collective memory crucial for transmission to future generations [7]; 2) The inherent strategic significance of the value chain stemming from the tourism sector underscores its pivotal role in shaping and influencing various interconnected aspects of economic, social, and cultural dynamics [8].

According to the Charter, heightened attention is warranted for additional issues, notably the increasing concerns about the degradation of cultural heritage, the diversification of cultural heritage tourism in the interdependence of their tangible, intangible, cultural, natural, as well as past and contemporary dimensions. Moreover, the Charter emphasizes the significance of perceiving heritage, the foundation of tourist activities, as a shared and collective resource.

Furthermore, in many European regions sustainable and cultural tourist strategies and activities frequently extend into territories where marginalization, progressive depopulation and abandonment processes represent critical dynamics. In Italy, in recent years these fragile territories have been supported by public policies which directed the greatest efforts in terms of investment in technological, infrastructural and service innovation. Enhancement strategies for the tourism sector can benefit communities and users, particularly influencing choices related to their free time and leisure activities, the perception of cultural heritage values and different accessibility and mobility modes [9].

In Italy, the opportunity to develop new tourist infrastructures and strategies was offered by the Piano Nazionale di Ripresa e Resilienza (PNRR – Turismo 4.0, which allocated 6.68 billion euros to tourism and culture, of which 2.4 billion were dedicated to Tourism 4.0 [10])[1]. These funds were divided between the competitiveness of tourism businesses, large tourism events and the construction of the digital tourism hub. In particular, the Sardinia Region, that is one of the Italian regions where the tourism sector has a great impact on the development of the territory, structured some policies included both in strategic plans and in specific projects (Strategic Development Plan and Tourism marketing of Sardinia 2018–2021, RESET Project - Territorial Network of Provincial Tourism Development and Experimentation 2022–2023, ANCORA Project 2023–2025 of the GAL Anglona Coros). In all these different plans the intention to innovate the region's tourism system at different scales of action emerges, by investing in its territorial capital - as conceptualized by Camagni ed al. [11], Camagni [12] and Fratesi and Perucca [13]- in order to intercept and attract new tourist flows and break down the seasonality framework typical of seaside tourism (which concentrates activities in about 120–150 days), thus becoming a destination of interest for different markets.

Researchers have widely demonstrated that the COVID-19 crisis has strongly underscored the numerous contradictions experienced by marginalized communities. This unfolding situation has also opened up opportunities for growth also for territories considered fragile and lacking in a recognized or valued tourist identity.

[1] PNRR or National Recovery and Resilience Plan (NRRP): is part of Next Generation EU, an economic recovery project dedicated to member states. The investments and reforms included in NRRP-Italy will make the country more territorially cohesive, with a more dynamic labour market and without gender or age discrimination. Public health will be more modern and closer to people.

Therefore, this article proposes a methodological approach aimed at supporting local authorities in designing tourist itineraries by considering the stakeholders' preferences and evaluating the socio-economic characteristics of the considered territory. In particular, this article aims to reflect on the future of the Anglona Coros an inner and fragile territory in the Sardinia Region (Italy), as a potential area of tourism development, starting from the results achieved by means of a survey based on a Conjoint Analysis (CA) model [14]. These preliminary results are analyzed and tested by applying the methodological approach developed in the context of the research project of national interest (PRIN 2017) "B4R - Branding4Resilience", which was based on the integration of different qualitative and quantitative tools and methods to explore inner territories and define enhancement projects.

The article comprises five main sections: the first one outlines the international and national context for exploring the fragile context connection with tourist attractiveness and delves into debates on sustainable and cultural tourism. The second section details the methodological approach outlined and applied to a case study in the Sardinia region, which is presented in the subsequent section, while the fourth section comments on the results achieved. Lastly, a discussion on potential themes for constructing sustainable and cultural tourism strategies aligned with territorial decision-makers choices is reported in the final section.

2 Background

Fragile areas today are affected by profound changes offering a compelling space for interesting research and experimentations. Numerous fragile areas, characterized by emerging risk factors such as depopulation, territorial inequalities, underscore the need for proactive actions and policies to rebalance the presence of basic services. These necessities non only addressing immediate challenges but also fostering socio-economic development. These themes deepened within the National Strategy for Inner Areas [15], signaling an urgent call to action for comprehensive support and strategic planning.

Beyond being merely associated with issues of marginality, degradation, and abandonment, these territories are recognized as having potential for revitalization and development. This potential can be unlocked with support policies and strategies that enhance the perception of places and their use through interconnections between sustainable tourism and cultural heritage [16].

Facing these challenges, the role of local authorities remains central in supporting these processes, as policies can balance short-term economic benefits and impacts with long-term sustainable development strategies [17]. The territorial asymmetries issue, linked to economic-social inequalities and the need to integrate sustainable development into cultural heritage tourism, requires synergies between territorial enhancement policies and those of subsidiarity [18], i.e. a harmonization between guidelines at national level and planning policies at local level.

Furthermore, cultural peculiarities linked to local resources could strengthen the identity and the economy of the local communities, by creating new jobs, increasing the residents' quality of life and the visitors' enjoyment, improving the image of the city and attracting new investors.

According to Europa Nostra [19], modeling and building a local identity becomes a "competitive advantage" that uses the concept of the so-called economy of uniqueness, in coherence with the UNESCO Recommendations [20] both on historical urban landscapes. Landscapes are the result of a historical stratification of cultural and natural values and attributes, continuously expanding beyond the notion of "historical center" or "ensemble", to include a broader urban context and its geographical location.

Some studies (i.e. [21]) also underlined that strategic approaches for the sustainable development of these currently "fragile areas" can be based on the involvement of the local community in the decision-making processes, accompanied and supported by awareness campaigns, educational and information programs, collaborative platforms organized by and for the community, to promote their own sense of identity and connect to their culture.

Furthermore, other research topics were addressed towards the demand side and its preferences [14, 22], the preferences of users of these areas were detected, not only in relation to traditional tourist experiences, but also to itineraries which enhance the material and immaterial values of these territories.

This system of values is bequeathed to future generations and translates into components of individual and collective utility and increases the collective well-being and quality of life [23].

Furthermore, in the last few years the research project of national interest (PRIN 2017) "B4R - Branding4Resilience" widely contributed to the debate on the potential of branding in addressing resilient territorial development strategies in four Italian inner territories. The B4R research project also developed a methodological approach based on integrating different qualitative and quantitative tools and methods to analyze fragile territorial contexts and define sustainable enhancement projects [9].

In particular, cross-dimensional exploratory analyses were performed and tested to structure coherent and updated knowledge bases able to support the activation of tourist and cultural strategies and/or the interaction among different stakeholders involved in real decision-making processes [24–29].

The research themes of the debate just mentioned constitute the references on which the methodological proposal and its application to the Sardinian context (Italy) were based, illustrated in the following sessions.

3 Methodological Approach

In the considered framework, this paper proposes a methodological approach, which combines a participatory process (activated through a survey based on the application of a Conjoint Analysis Model) aimed at designing a tourist itinerary with the B4R Exploration approach, aimed to analyze the territorial potential of "fragile" territories by means of spatial analyses based on cross-dimensional indexes and indicators.

Figure 1 shows the methodological approach to macro-phases and micro-phases, highlighting a process that can be used in the initial phases of decision-making processes to support the design of public strategies.

Establishing the research objective (**Phase 0**) is essential for delineating both the geographical boundaries and possible thematic or methodological constraints.

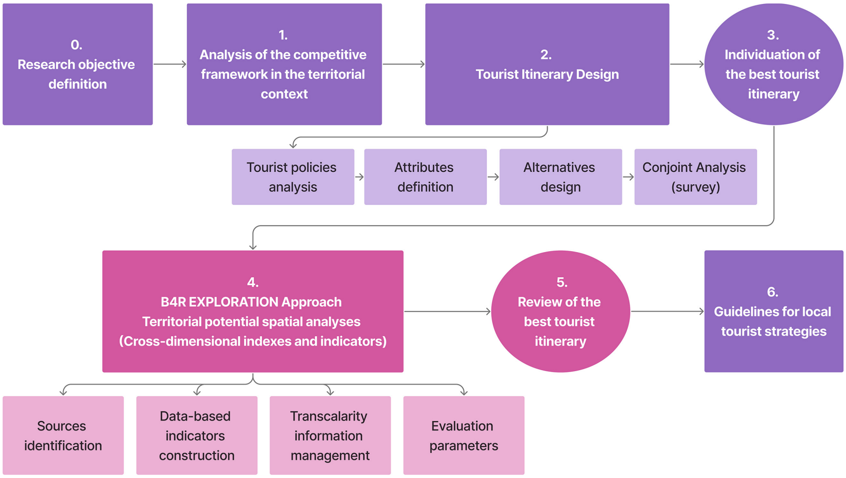

Fig. 1. The methodological approach (Source: Authors' elaboration)

The analysis of the competitive framework in the territorial context (**Phase 1)** is based on activities of data collection and knowledge construction, to understand the characteristics and peculiarities of the area (cultural heritage, natural resources, territorial planning and "intangible" heritage). The outputs of this phase consist of: 1) understanding the territory's vocation, evaluating its strengths and weaknesses, 2) identifying a user base interested in undertaking this type of experience, and choosing alternative ways of enjoying the cultural heritage of the sample area.

In the tourist itinerary design process (**Phase 2**), the analysis of local tourist policies and the definition of attributes and alternatives are fundamental micro-phases to structure a survey and apply the Conjoint Analysis (CA) technique to estimate the value of a public good, the willingness to pay (WTP) in evaluation processes, and the levels of utility and preference for potential final users [30–35], indirect and implicit manner through the use of this attribute.

As described in Coscia and Pasquino [14], the Conjoint Analysis (CA), coined by Green [30], is used to indicate methodologies aimed at analyzing multi-attribute scenarios: in these cases, the multi-attribute nature of cultural assets, lends itself very well to carrying out an estimative analysis of such assets. The technique was applied in the form Conjoint experiment (CE) based on the RUM model [36]: this involves the user indicating which product they prefer within a set of products with different attributes (Most Preferred Choice). Furthermore, the inclusion among the other attributes of the "cost" element allows the WTP not to be detected through a direct question (as happens in CV), but rather in an indirect and implicit manner through the use of this attribute.

The designed alternative itineraries are presented to both residents and visitors: the outcomes entail identifying and formulating the "best tourist itinerary" encompassing individual activities evaluated with the highest marginal utility (**Phase 3**). To verify and eventually modify the "best tourist itinerary", territorial potential spatial analyses can be performed by means of cross-dimensional indexes and indicators (**Phase 4**). This phase can be carried out by defining a series of evaluation parameters (opportunities and threats) specific for each analyzed territory, whose presence may suggest modifications to the chosen route as including new stages that can serve as attractions for different types of tourists. As the B4R Exploration approach suggests [9, 24, 25], these indexes and indicators can be organized and structured into four exploratory dimensions, each addressing specific themes to emphasize significant trends within the identified sample area. These data-based analyses can be performed by building a Geographical Information System (GIS) that through the use of multi-scale geo-referenced data allow the construction of synthetic spatial indices and thematic maps [37] useful to highlight the territorial potential and to eventually modify the "best tourist itinerary" (**Phase 5**).

Only through geographic information, it is indeed possible to simultaneously observe phenomena belonging to significantly different scales and cognitive dimensions (e.g., tourism and geomorphological risk, hospitality and administrative vitality), enabling the assessment of their risks and benefits, and re-thing development strategies and design solutions.

Once the best tourist itinerary is validated or revised, some guidelines for local tourist strategies can be outlined in order to support local authorities in the activation and development of enhancement strategies and actions (**Phase 6**).

4 The Focus Area (FA): The Territorial Area of the Anglona Coros (Italy)

Following the Strategic Regional Plan[2], the present research analyzes the Italian area of the Anglona Coros in the North of Sardinia, assumed as Focus Area (FA). The FA, though lacking direct access to the sea, is strategically located near pivotal hubs like the city of Sassari, Alghero airport, and Porto Torres harbor. Despite the presence of architectural heritage and landscape value, it remains relatively underdeveloped and unknown. The FA corresponds to the historical sub-regions of Anglona and Coros, characterized by a diverse landscape that transitions from predominantly flat zones intersected by a complex hydrographic network for agricultural cultivation and grazing, to rugged terrain marked by extensive outcrops of rock, often forested or covered in scrubland. At present, this territory includes 17 municipalities (Osilo, Nulvi, Tergu, Martis, Laerru, Sedini, Bulzi, Santa Maria Coghinas, Perfugas, Erula, Chiaramonti, Ploaghe, Codrongianos, Ittiri, Cargeghe, Muros, Florinas) and spans across 827.25 km^2. Following the endorsement of the Regional Rural Development Plan (2007–2013), the Anglona-Coros Local Action Group (Gruppo di Azione Locale - GAL) was established, comprising local private and public stakeholders following European regulations [38].

The socio-economic challenges hinder the optimal appreciation and protection of the cultural and natural heritage in the FA, despite its abundant offerings such as touristic offer and natural sources. Recognizing the full spectrum of cultural assets (architectural and natural elements) is crucial for unlocking their economic potential. The area

[2] The Strategic Regional Plan (2028–2021) predicted for all Region the ZES (Zona Economica Speciale), see: https://www.regione.sardegna.it/documenti/1_231_20181221121007.pdf and https://delibere.regione.sardegna.it/protected/44771/0/def/ref/DBR44772/

is increasingly leaning towards promoting slow tourism, highlighting immersive experiences within the territory and encouraging meaningful interactions with local residents and their surroundings. A closer analysis of the territory reveals a rich historical, archaeological, cultural, and identity-based heritage spanning various epochs, from Paleolithic settlements through the Nuragic period to the Early Middle Ages. Notably, the Northern Sardinia region houses 70% of the island's Romanesque churches, some of which are already part of a visitor itinerary supported by the European Regional Development Fund INTERREG (Itinerario Romanico). The region also boasts diverse natural assets, ranging from leisure-oriented areas like parks and the natural thermal baths of Casteldoria currently closed to the public - to sports focused areas with challenging terrains, cliffs, and caves, exemplified by the SIC site Grotta de Su Coloru.

5 Results

The proposed methodological approach was tested on the identified FA, managed by the Anglona Coros GAL, which was selected due to its fragile socio-economic context.

It is worth mentioning that the Regional Rural Development Plan categorized the FA as a "rural area facing comprehensive development challenges" and highlighted its condition of "extremely critical" demographic disease (SMD) in various municipalities.

Examining the ISTAT data from the period 2014–2021 reveals a notable increase in extra-hotel accommodation capacity, particularly since 2019. Regarding visitor arrivals and stays in 2021, the area recorded 13,918 stays (in 2018, pre-COVID period, were 2,950) and approximately 3,000 arrivals (in 2018 were 1,127). Tourist influx is understandably concentrated in the summer months, notably August, with some presence in June and October. The average Stay Index stands at 5.4 days, and the Italians stands at 4.1 days.

Therefore, this research aims to support the Anglona Coros GAL in designing a tourist itinerary by considering the stakeholders' preferences and evaluating the fragile socio-economic characteristics of territorial context.

5.1 Tourist Itineraries Design and Marginal Utility Evaluation Through a CA Model

The design of alternative tourist itineraries was based on a thorough and comprehensive analysis of the competitive framework, which included consultations with some key stakeholders operating within the area. A participatory process was activated through a survey based on the application of a CA model, aimed at investigating both willingness-to-pay metrics and user preference curves. To discern users' preferences, four principal attributes were identified to describe valuable characteristics of the area, with particular attention to cultural heritage assets, understood both as natural and historical resources and intangible resources related to local traditions (i.e. handicrafts, local festivals, and customs, etc., see [14, 39]).

These four attributes were structured into three levels, as outlined in Table 1. The combination of these attributes and levels led to the creation, by means of IBM SPSS27 software, of nine alternative tourist itineraries for enjoying the FA.

Table 1. The tourist itinerary attributes and levels (Source: Coscia and Pasquino, 2023)

CULTURAL HERITAGE	SPORT, GREEN, FITNESS	FOOD AND WINE	TRANSPORTATION
Conservation and protection of cultural heritage in the state of fact	Conservation and protection of green areas in the state of fact	No food and wine experience	Transportation vehicle to be provided by the user
Enhancement of the Nuragic period itinerary	Enhancement of recreation places and green areas	Enhancement of stops for tasting of traditional dishes	Use of a shuttle
Enhancement of the Medieval era itinerary	Enhancement of places for sports activities	Experience inside a local business	Use of an electric car

ATTRIBUTES + LEVELS COMBINATIONS

↓

9 ALTERNATIVE TOURIST ITINERARIES

Subsequently, the alternatives were evaluated by means of a survey, which was completed by a sample of 600 respondents (301 GAL residents and 299 tourists) who expressed their preferences for them. The Itinerary n. 6 (see Fig. 2) emerged as the best one on the basis calculation of utility values and the related economic surplus [14, 39].

This itinerary expects the conservation and protection of the cultural heritage, the enhancement of outdoor sports activities, the local businesses' involvement, and the implementation of electric cars to be used within the area.

These results from the CA model application outlined key elements consistent with possible tourist strategies and actions to be developed by local authorities.

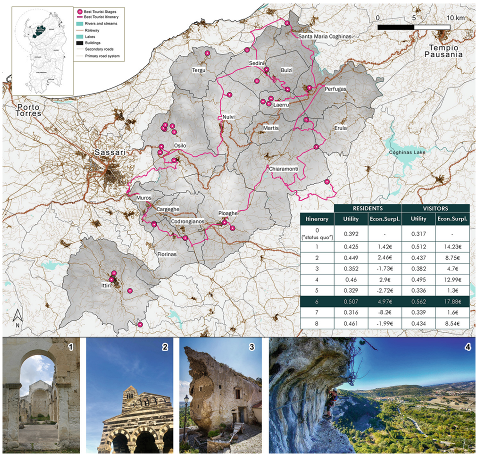

Fig. 2. The best tourist itinerary in the FA (Itinerary n. 6). (Source: Authors' elaboration). Architectural heritage images: 1) San Nicola di Sinis Church, Sedini (Source: Francesca Pasquino, April 2023), 2) Basilica of Saccargia, Codrongianos (Source: Francesca Pasquino, January 2023), 3) Domus de Janas, Sedini (Source: Francesca Pasquino, April 2023), 4) Hiking in Osilo (Source: www.informati-sardegna.it).

5.2 Review of the Best Tourist Itinerary Through the B4R Exploration Approach (Territorial Potential Spatial Analyses)

The consistency of the best tourist itinerary, that emerged from the CA model application, was tested by applying the B4R Exploration approach, based on territorial potential spatial analyses, in order to identify opportunities and threats not emerging neither from the analysis of the competitive framework nor from the CA model and to verify and, if necessary, modify the identified itinerary. In particular, the approach was performed by applying some cross-dimensional indexes and indicators related to the Dimensions n.1 and 2 of the B4R Exploration approach [9, 24, 25].

The B4R Dimension 1 issues ("Infrastructure, landscape and ecosystems") focused the attention on the FA infrastructural networks and connection and highlighted the presence of inadequate and obsolete infrastructures. Since it is located far from the sea, the Anglona Coros territory lacks efficient connections, especially during the summer season, isolating the municipalities from seasonal tourist flows. Furthermore, currently there are no direct connections via public transport to Fertilia airport and Porto Torres harbor and only 7 of the 17 GAL municipalities have a railway station. The municipality of Santa Maria Coghinas does not even have a bus station, making it impossible to reach the municipality by public transport. As regards sustainable mobility, the "Sassari-Ozieri" cycle path, as part of the "Ciclovia della Sardegna" project developed by the Sardinia Region and the regional transport company ARST, passes through the municipalities of Muros, Cargeghe, Codrongianos and Ploaghe.

The B4R Dimension 2 issues ("Built and cultural heritage, settlement dynamics") outlined the richness of the FA cultural sites, folkloristic heritage and architectural assets and related to the Paleolithic, the Nuragic period, as well as the Middle Ages.

Furthermore, the analyses highlighted the presence of valuable naturalistic elements that, unfortunately, are often neglected in terms of conservation and promotion. The landscape and naturalistic assets, such as natural parks, lakes and spas, could constitute tourist attractions to be redeveloped and made accessible to the public, thus encouraging new forms of sustainable tourism. The spatial analyses also pointed out the accommodation facilities present in the area in terms of number of beds.

Based on these observations, the following 4 evaluation parameters were established to verify and modify the best tourist itinerary that emerged from the CA model application:

- Proximity ($<$ 3 km) to municipalities with a high presence of numerous accommodations;
- Proximity ($<$ 1 km) to municipalities with a low level of cultural offerings;
- Proximity ($<$ 1 km) to the access of parks and protected natural areas;
- Proximity ($<$ 1 km) to other existing tourist itineraries or isolated attractions.

A positive value to one or more of these evaluation parameters suggested possible deviations in order to include other tourist strategic attractions.

In particular, the analyses performed by applying the B4R Exploration approach suggested two specific deviations, which could review the tourist itinerary n.6 and foster tourist development even in municipalities with a weak socio-economic context characterized by a low tourist offer (see Fig. 3).

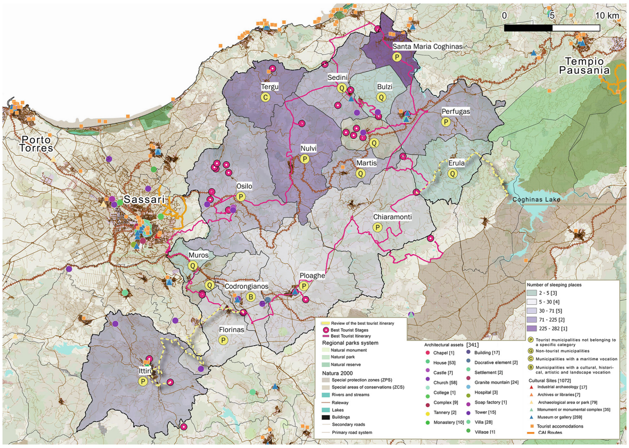

Fig. 3. Review of the best tourist itinerary based on territorial potential spatial analyses (Source: Authors' elaboration).

The tourist itinerary n.6 was identified as the fastest route capable of connecting all the municipalities in the area, with the exception of Tergu, Martis and Ittiri. Therefore, the first proposed deviation was aimed to include the municipality of Ittiri, where there are Romanesque churches, which deserve to be enhanced and enjoyed by tourists.

The second proposed deviation consisted of including the municipality of Erula as a possible starting point to visit and enjoy the Coghinas Lake and the neighboring Limbara Natural Park. This proposal was aimed to encourage an increase of the provided sports and leisure activities in this valuable natural environment, as well as to foster the opening of new accommodation facilities, which are currently lacking in this municipality.

By considering these new stages, the proposed tourist itinerary should last 3–4 days, starting from Osilo and including overnight stays in Ittiri and Erula before going back to Osilo.

This itinerary can be considered a strategic action that the GAL should develop and implement to enhance the Anglona Coros area from a tourist, cultural, environmental and economic point of view.

6 Conclusion

The FA investigation, traditionally perceived as a marginal territory, however, has highlighted many potentials that are not currently known, in particular if seen from the perspective of sustainable cultural tourism policies. Therefore, these initial explorations and findings have significantly advanced research in several dimensions and in particular:

- definition and knowledge of inner areas: within the Italian national context, the research has explored and understood the phenomenon of an area affected by territorial imbalances expanding the panorama of Italian research in this field, thanks to the experimentation on this territory of an integrated methodology, which has never been applied until now

- methods and tools: the research has experimented with and integrated qualitative-quantitative approaches to the investigation of territories through multidisciplinary perspectives capable of grasping the different conditions of marginality, the gaps to be identified and the different trajectories of transformation in different contexts. The integrated exploratory investigations highlight numerous potentials for analysis and support for decision-making, even in contexts such as the sample FA, where information and databases are sometimes incomplete or not systematized and interoperable.
- approach to sustainable cultural tourism strategies: the research emphasizes the need for strategies that consider the varied needs of the different targets, protecting the system of values that these territories express through their genius loci, in order to implement glocal, collaborative and complementary visions between territories. In particular, for the FA it brought out some elements for the construction of some planning and territorial governance strategies: 1) the need to invest in infrastructure in a sustainable way (electric cars, cycle tourism, etc.), 2) the importance of processes of loyalty to the tangible and intangible heritage of residents through the "discovery" of their territory not in a "hit and run" mode, but in a slow mode with stopovers and overnight stays, 3) the centrality of strategies for deseasonalization of tourism, not only summer tourism and seaside
- processual and strategic approach: The research advocates for overcoming the opposition between top-down and bottom-up actions, reinterpreting the collaborative modality and also enhancing the action of actors such as the GAL, who can represent those intermediate bodies indispensable for awareness-raising actions and involvement of local communities.

With these multiple perspectives, the conditions of marginality and fragility, that emerged from the phase "CA process linked to Exploration", are analyzed, in order to provide a methodology to support decision-making: this methodology can constitute the tool capable of reactivating the dialogue with the Public Administrations of the FA and with all the stakeholders. For the FA, the municipalities of the GAL have already shown interest in the results of this preliminary exploratory phase and can become actors in the decision-making process and in attracting financing and funds through proposals for sustainable itineraries.

Furthermore, the integrated methodology has shown further possibilities for refinement and synergy between the CA process and the cross-dimensional exploration analysis, which can be tested together from the early stages of the methodology: this will constitute a future development of the research.

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Concepts and Tools for the Emergence of the Axiological Subject in the Prospect of Territorial Rebalancing

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Abstract. This study concerns the definition of certain conceptual aspects underlying territorial disadvantage as a consequence of the unbalanced individual-community relationship in its ontological and epistemological foundations. Some disciplinary premises of evaluation science define the scope of interest, in particular the relationship between individual and collective interest, the concept of freedom, and the definition of the personal sphere as the constitutive parterre of ordered communities. Emerging in this in-depth study is the role of agency in the areas of exchange production and assessment, the latter addressing Appraisal's responsibility in abstaining from taking a position with respect to the progressive drainage of demographic and territorial resources, despite the potential of the real estate analysis tool. Some references to the question of economic freedom and the importance of this capacity in the reform of the collective axiological order prepare some philosophical reflections on the possible reform of the economy and of the representation of the territory in order to recover its human dimension and its many dispersed identities.

Keywords: Individual-community relation · person and liberty · territory as relational entity

1 Introduction. Disciplinary Premises for the Role of the Subject

The issue of territorial rebalancing involves many perspectives and prospects. For their unity and consistency, the disciplinary context of the 'science of assessment' must be defined and described. Traditionally, the scientific approach to valuation has been identified as Appraisal, usually assumed to be the set of methods, techniques and tools helpful in assigning consistent and probable valuations to the land-urban real estate assets. The privileged reference of these estimates has always been the market, albeit typically imperfect; consequently, the accountability of the estimate calls into question the scientific, professional and intellectual responsibility of the estimator, both in terms of third parties (personal reliability) and truthfulness (social accountability).

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Another difficulty affecting the evaluator's scientific and operational positioning of evaluator relates to the nature of "applied science" that characterizes appraisal, defined by [1] "a cognitive and operational stage of economics". Depending on the bundle involved, a possible broad definition of Appraiasal as the actual Science of Valuation follows: "The science of valuation concerns the attribution of a value judgement to the stable forms of the home-city-landscape system and to the evolutionary processes that affect it, causing changes that result in significant redistribution effects in space and time of real and monetary wealth".

This leads to two important aspects of evaluation, both of which are necessary to define the profile of this discipline and its civil engagement: the first concerns the nature of evaluation, the second its appropriate application. This twofold dimension of the science of valuation is implied at the heart of the proposed definition with regard to the two fundamental categories of judgement and value: the first, as linguistic-cognitive category, concerns the ability to distinguish, evaluate and choose; the second, as an ethical category, concerns decisions by defining the content of the evaluative proposition itself. While judgement refers to the conditions of truth of evaluation, value refers to its conditions of authenticity, i.e. references and contents: the value bearers, the valorizing substance, the subjects involved as both original agents and ultimate ends.

Although both "true" and "just", as "super concepts", involve the dimension of the subject, the doctrinaire Appraisal – mostly intended to defend the general validity of evaluation, assumed as public relevance – has neglected subjectivity according to the perfect market narrative, where nobody can influence prices, whose ethical relevance is determined by social relations, assumed as spontaneous, therefore natural, and therefore just. Nevertheless, the dimensions of subjectivity, such as arbitrariness, discretion, jurisdiction, etc., are deeply rooted in the sphere of judgement that is the fundamental human faculty, for better or for worse.

To better understand the significance of subject, "subjectivity" should be understood as Subjectiveness, that is, the quality of dealing with the subject, as complement to Objectiveness. Accordingly, while a subjective evaluation might be considered partial or distorted by personal and unpleasant opinions, the Subjectiveness of an evaluation is precisely its referability to a Subject. In philosophy, Subject is "the 'I' or spirit or consciousness as the determining principle of the world of knowledge, or action, or at least as the capacity for initiative in that world"; in particular, for Kant, the "'I' is subject insofar as it determines the union of subject and predicate in judgements, that is, insofar as it is synthetic or judgmental activity, cognitive spontaneity, hence consciousness or self-consciousness or apperception" [8]. These extensions of the notion of the subject to the realm of consciousness, and its direct connection to the realm of judgement, should encourage Appraisal to re-evaluate subjectivity as a relation to the subject, that is, Subjectiveness.

For our purposes, Subjectiveness refers to the individual and collective "emergence of the subject" in all three areas of evaluation: production, exchange, assessment.

In order to center the concept of Subjectiveness in this sense and in this disciplinary context, two further clarifications may be useful:

1. Subjectiveness refers to "agency" a capacity associated with the intentionality of action. According to the "hermeneutic theory of action", agency (typically the capacity to make things happen), in the field of value and evaluation is the capacity to create added value: if the value created is authentic, this agency is the capacity to act with judgement, to discern the good, the beautiful, the just. These qualities are neither exclusively individual nor exclusively collective, and there can be no delimitation or typology that allows for any prejudicial distortion or ideological appropriation.
2. The difference proposed here between assessment and evaluation is intended to highlight the relevance of the former to the individual in relation to the collective dimension of the latter, hence its civic function. Assessment is a specification of evaluation carried out with a view to supporting choices concerning the corpuscular facts of production and exchange. Evaluation, on the other hand, is a cognitive process extended to the whole sphere of the reasons and motivations that inspire agents in their interaction: the result of evaluation is the awareness of the actual creation of "authentic value". The value created is authentic to the extent that the underlying process does not disadvantage anyone, directly or indirectly, in space and time. Estimation, i.e., the answer to a specific question, is a more or less extensive part of this awareness. At the lowest level of awareness, estimation is a mere statistical processing; at the highest level it may even deny that added value exists, because, in reality, no process creates value, but rather transfers it and, especially in property and urban development, concentrates it.

The capacity to create value is expressed, and therefore justified, in progressively wider areas of being worth: firm, industry, territory, nation, development model. The net result of a company is welcome even if it is achieved at the expense of workers made redundant after a merger; we all hope that market prices will fall, although we know that this depends on the failure of inefficient companies; the higher real estate performance of a metropolis is always supported by the outflow of population from the smaller hinterland centers; there is no doubt that the Global North will never abandon a development model that is as unsustainable as it is (increasingly) unfair to the Global South; the problem of migration doesn't allow for a peaceful solution.

The inclusion of agency in the economic-evaluative narrative implies the "subject as presence" and, in the prospect of territorial re-balancing, a presence in the relational and axiological dimensions. The hope of a territorial and generational balancing is subordinate to this. In fact, social communication unfolds in its authentic form where and on condition that it gives shape and presence to the sharing of limits and destinies.

2 Liberty Between Individual and Communities. Genetic Epistemology and Phenomenology of Person

Some suggestions about the directions of sharing limits and destinies to extend the field of agency include the biological foundations of the relationship between individual and community, as well as the phenomenological definition of person and freedom.

2.1 Individual and Community

According to the genetic epistemological approach of H. Maturana and F. Varela, based on the "identification of knowledge and action" the evolution of the social agglomerates and the identification of the social systems as unitary recognizable entities, are the result of the "structural ontogenetic coupling, whose diversity, heterogeneity and plurality are due to pluricellular variant or deviation". "Evolution is a natural drift produced by invariance, autopoiesis and adaptation" [2]. Adaptation, as a success factor in the evolution of a species, is an invariant selected through the evolutionary drift itself [3].

"Social systems are the result of communicative behavior, i.e. behavioral coordination processes in a domain of structural coupling" [3]. The existence of living beings depends not only on competition (which creates unequal advantages and disadvantages) but above all on the maintenance of adaptation through interaction between individuals leading to the survival of the best adapted.

The biological metaphor relating to the most complex living beings, the multicellular organisms with a nervous system, provides, by contrast, a meaningful characterization of human social systems in view of the role of language. The dialectic between individual components and the organism as a whole is reverse between natural and human organisms. In nature, "the organism limits the individual creativity of its constituent units, so that the units exist as a function of the organism; the human social system, on the contrary, expands the individual creativity of its components, so that the system exists as a function of the components" [3].

The primacy of the individual is one of the main themes of the liberal political-economic narrative involving the concept of altruistic selfishness anticipated by B. de Mandeville in The Fable of the Bees [4], which has provoked much debate in moral philosophy and economics. In the former, it was accused of devaluing religion and virtue and recommending luxury, avarice, and pride (G. Berkeley), of misinterpreting the very concepts of pleasure and luxury (F. Hutcheson), of understanding greed as part of self-interest, distinct concepts that influence the market in different ways (A. Smith), of considering a society based on social polarization as flourishing (L. Holberg), of excluding compassion and solidarity from individual desires (J.J. Rousseau), of prejudicially identifying desires with evil impulses and wealth with social welfare (L. Stephen). In economics, The Fable of the Bees is reflected in the principle of effective demand, according to which one of the causes of unemployment is insufficient demand and an excessive saving, which can be curbed by supporting rent rather than wages and profit (T.R. Malthus) or, recently, the propensity to consume (J.M. Keynes). Indeed, both Mandeville's critics and his supporters seem to agree with the present, the former adopting a normative moral perspective and the latter a pragmatic approach to the relationship between the individual and the community.

2.2 Politic Liberty. Negative and Positive Perspectives

A note on an overarching concept of liberty comes from some premises on the issue of the person as subject of free acts, addressed by R. De Monticelli [5], which inspires the following basic concepts supporting the issue of communities and territories identification process. With reference to the two attributes of liberty – negative and positive – from the contribution of I. Berlin [6], De Monticelli proposes a well-founded interpretation that we consider crucial for a constructive synthesis of this concept in relation to the solidary link between individual and community, as well as between local and global identity, which we try to synthesize below.

The negative concept of liberty underpins liberal politics, to which the positive concept is opposed, thus laying the foundation for totalitarian. The negative sense of liberty refers to the "the possibility of acting to pursue one's own well-being in one's own way and without interference from others". The liberal narrative assumes that freedom is a value to be defended in itself, an ultimate end that is not ancillary to justice, happiness, the fulfilment of the person. The negative sense of liberty refers to any denial of this possibility, even if it supports the values mentioned above.

The positive concept of liberty refers to an "orientation of the will towards values" to which liberty is subject. Berlin does not believe that positive values imply each other, and therefore assumes the ineradicability of personal and social conflicts because of such an incompatibility of human ends. Therefore, freedom of choice is an overriding value to be protected by extending the "sphere of non-interference".

The advocates of the positive conception of liberty, on the other hand, recognize the social subject who directs freedom in the role of its defender and not with those who "confuse the value of life and of the human person, which is certainly not negotiable, with the goods in which it is embodied for him/her and according to him/her".

Berlin's criticism of the positive conception of liberty is based on the rejection of the contradiction within the individual, concerning the transcendental moral component that dominates and subdues the bundle of desires and passions, the full expression of which one must frustrate in order to be happy.

The formation of the subject as a political entity is rejected by Berlin because he understands positive freedom as 'the content to be given to free action'; therefore, the reference to the polis as the matrix of the orientation of the will towards certain values is to be considered illiberal. De Monticelli, on the other hand, highlights the metaphysical meaning of authentic freedom: free will is independent of individual values but concerns the very nature of the person, which is not "a mere political metaphor" [5].

For our purposes, any argument in favour of the continuity of the axiological personal and social fabrics (in its territorial "epiphany") – and thus the reference to the aspects of will and responsibility – contributes to presentation of the most significant conditions of territorial disadvantage with a view to reducing them.

De Monticelli argues that the most pertinent explanation for the prominence of both perspectives of liberty, negative and positive, does not concern the combination of two spheres in which liberty must be guaranteed (the former) and cultivated (the latter) in order to be fully exercised. Rather, it concerns the clear formulation of the "metaphysical question of liberty", which questions the "nature of voluntary agents and their liberty", i.e. the nature of the person [5].

2.3 Person, Liberty and the Social Being

Free choices and ordered decision-making processes develop according to the dialectic between the individual and the community. The following points are drawn from the broad and deep analysis and synthesis that De Monticelli [5] offers on the "person as subject of free and novelty-bearer acts".

According to M. Scheler, "the person is the 'performer of acts' or 'bearer of acts' and the 'world' is the objective correlate of the person" [7].

According to the development Scheler research development from De Monticelli:

Person: a comprehensive definition. "The person is the subject of free acts, by means of which he or she rises above his or her own physical, psychological, temporal, environmental and social states, and is then the bearer of novelty by virtue of his or her positionality, agency, actorhood". The first is the ability to have an opinion, the second to be aware of one's actions, the third to be responsible for one's actions.

Such a definition places the personal dimension of each mature individual as the primary and original reference of the creation of *added value* (novelty) and at the basis of the development of ordered place-based communities.

Subject. To be a subject is an "experience of power", an act of will that modifies and transcends the ordinary state, hence the ability to act out of duty or obligation, to realise a vision, to achieve the objectives of a mission.

Free acts. Free acts can be defined in the broad sense and in the proper sense. Free acts in the broad sense give rise to a personality that identifies a human being intrinsically, i.e. through a motivational style and the content of a path of experience; free acts in the proper sense, or self-constitutive acts, give rise to a personal identity that is attested through time with present responsibility for the present, past and future itself. Spatio-temporal responsibility, which allows the integration of the dimensions of space and time, makes persons subjects of free acts that constitute ordered communities.

Emergence: persons and communities. Individuals are formed within a stream of experience that is largely defined by the social context. If, when, and to the extent that the individual succeeds in objectifying ideas and feelings from the experiences in which he/she has long been immersed, he/she emerges from them as a bearer of novelty, as a person. Primary objectification is the recognition of the way the world works and the experience of trust in objective reality, thus accepting the laws of the physical world and the rules of the social world, accepting them and living in and for them. This objectification consists in taking the right position on things by sharing perceptions and emotions. The context of this emergence is the "community of life", in which the shared values are learnt "by contagion", at the lowest level of social learning, and "by tradition", at the highest level. This level of consciousness is necessary in order to conform to social conventions, to be truly part of the community, to share the "basic fusional part of sympathy. This is "being born into the world as subjects" of an ordered world. The achievement of such a social placement is the first step of being subject, the one of primary identification. Primary identification is the first level at which a person rises above his/her states and acquires a subjective pole and an objective horizon. This is the level of "subjectivation" of persons who "come into the affective human environment that welcome them". While primary individuation involves free acts in a *latu sensu*, secondary individuation involves free acts *strictu sensu*, the self-constitutive ones, shaping a personal identity that is established over time with current responsibility for the past, present and future, the secondary identification place person in the social universe. "The personal identity that emerges with secondary identification is what we make of our biological and social identity, that is, what we make of what is determined by the individual genome, by the circumstances in which we are born, in that tradition, in that culture, in that community of life".

This difference between primary and secondary individuation is present in Appraisal and Valuation, which focus on the surplus created by the dialectic between ordinariness – which ignores the agency and positionality of the subject, but also its responsibility, which is neutralized by the a-personal characterization of the market – and extraordinariness, that is the "furtherness" of the subject who engages in and strives to emerge from this socio-economic state. The phenomenology of the person is particularly interested in how the agent-person can create or destroy value across the whole spectrum.

Secondary individualization contains the elements for the connotation of the personal universe and the inseparability of its particular aspects from its totality, "a personal prospect to which corresponds a task, a kind of destination, a moral physiognomy".

This "heritage of furtherness" is what we call – more generally and in the phenomenology of the territory of settled communities – "landscape" the light of the whole that allows (or that could allow) the recognition of the authentic identity of a socio-territorial subjective. But also the task of those who are concerned with measuring the value of goods – and its variations, its differences, indicating how to increase it and how not to lose it – is given, implicitly, by the very fact of practicing (or teaching how to practice) value judgement.

The emergence from the socio-territorial states implies that, by taking a position and acting accordingly, the person emerges giving rise to the realization of values in new goods in a certain sense of axiological innovation, which is the typical mark of the design dimension of the Science of evaluation focused on the "reform of the order of values" and aimed at giving a new life to old things, as well as giving existence to new things.

3 The Perspective of Social Mutation as a New Territorial Identity Prospect

A surprisingly original and persuasive contribution by B. Latour [9] redefines the value/perspective system of a globalized community struggling with the new climatic disorder and on the planetary horizon of the experience of pandemic confinement, within a new kind of living space that is increasingly, fortified, introverted, asphyxiated.

Two aspects of it are relevant to the present question of spatial solidarity in support of territorial balance. The first concerns his harsh criticism of economy and economics. Economy, temporarily suspended due to environmental fluctuations, relies on complex state institutions, information infrastructures and econometric calculations to recover despite the inevitable traces of irreversibility: even in the economy, nothing is lost, nothing is created, everything is transformed. Latour points to the abstractness of the "scientific" representation of economic phenomena, which renders their (apparently) autonomous development mysterious and increasingly heteroctone the *homo oeconomicus* model.

"In order for the Economy to expand, to be held deep as the foundation of all possible existence on earth, it requires a huge amount of infrastructure building so as to impose it as a given and to overcome the tenacious resistance that most common experience exerts as a reaction to such violent colonization". Without all this technological, scientific, academic, political, administrative, and media apparatus "no one would have invented 'individuals' capable of such radical, assiduous, and coherent selfishness as to 'owe nothing to anyone' and to regard all others as 'strangers' and every form of life as a 'resource'" – Latour quotes Donald MacKenzie [9].

Similarly, Latour criticizes the representation of the territory, which abstracts the material support of the economy from concrete potentialities, needs and authentic values. Its geographical and topographical representation looks at it from above and thus from the back, fragmenting it into a series of parcels characterized outside their mutual relations. "An uninhabited territory even if not in its economic abstraction. Confinement has nailed people down, but finally rooted them "somewhere"; the common destiny of this confinement has restored social bonds: "to subsist, to group, to be on the ground, to self-describe" so that the territory can no longer be described from above (from outside out) but from below (from inside).

Describing the territory from the right means describing it from a grid of interdependencies: "what do I depend on for my livelihood; what are the threats to what allows me to live; what trust can I place in those who predict this threat to me; what do I do to protect myself from it etc."

The final suggestion of this work relates to the ability of a relational territory to reverse the depopulation drift by reversing the subject/object relation: just as territory can leave, so territory can "repopulate people" [9]. It should be noted that one of the main epiphenomena of territorial distress is the abandonment of large parts of the smaller built fabric and their progressive physical decay.

These challenges renew Appraisal's civic commitment in the field of territorial rebalancing, interpreting the two aforementioned pillars, subjectiveness and objectiveness, as meta-references of value judgement.

Latour's critique of the "view from above", i.e. through the abstraction of market quotations, applies to the question of the "anamorphic inversion" of the value/price relationship that the real estate economy has produced as its financialization has intensified, particularly in the aftermath of the 2007–12 crisis. The zeroing of house prices has deprived them of both practical and symbolic value. This has increased the fragility of small-town centers, discouraged investment in maintenance and refurbishment, and reduced the sense of individual and collective responsibility for passing on this heritage.

Consequently, if the market creates and exacerbates territorial inequalities, it cannot, in principle, be assumed to be the best economic communication mechanism and, operationally, the primary reference for evaluation; for the same reason, the market value criterion loses its relevance for evaluation in support of rebalancing policies.

In essence, politics coordinates joint action according to the criterion of "appropriateness", which is superior to the criterion of "rationality" (not necessarily "reasonableness") relevant to economics. The dialogue between economics and politics has always supported both the welfare state and the welfare economy, justifying appropriate and reasonable fiscal and monetary measures with a view to redress the balance.

Appraisal has much to say as an alternative to "market value", especially when "cost value" and "capitalization value" are taken in a heterodox sense.

The Cost value is to be understood in a historical and social sense, as a measure of the sacrifices that have given a unique and unrepeatable form to the built space and life to the relationships that signify it. Reproduction cost value" recognizes:

- in a temporal sense – and according to classical-Marxian economics – the conflict between capital and rent, between rent and labor, between labor and capital; the progressive rise and fall of the corresponding social classes is reflected in the resilient tracks defended by the physical inertia of the built heritage and the impenetrability of these habitats to current lifestyles;
- in a spatial sense – and according to the macroeconomics of sectoral interdependencies of W. Leontief – the "interrelations on which we depend" according to Latour, who identifies them as the condition for the "repopulation of the economy, territory and landscape".

The "capitalization value" should also be understood in a heterodox sense: in fact, as an economic index, the capitalization rate measures the productivity of the property, as a financial index it defines its risk-return profile. Evaluation in the field of the protection of the anthropic imprint of the human and social capital of local identities takes the capitalization rate as an index of the present/future dialectic and has the same meaning in the private sphere as the social discount rate in the public sphere.

Accordingly, even on the basis of value measured in terms of the cost of value, the concept and practice of real hoarding by the public should become the typical attitude of ordered communities committed to basing their prospects on the recognition of the qualities of value that make (mere) things goods in themselves.

Cost value operates in the realm of individual objectiveness and agency, capitalization value in that of subjectiveness and collective agency.

4 Conclusions

This study proposes some founding aspects of the of territorial disadvantage issue as a seemingly unintentional process justified as a natural effect of a process of wealth creation and concentration, supported by a condescension of dispersed agencies to transformations led by an apex agency. This process has also taken place in Italy, where it has followed all the metamorphoses of monetary and real hoarding, for the most part in conjunction with the development of industrial, real estate, financial capitalism.

The success of this deterritorialization has been accepted and unconsciously participated in, also endorsed by the Appraisal, whose ethical intentionality, or axiological non-neutrality, has been anaesthetized by the undifferentiated reference to the market.

The paper presents some conceptual references concerning the relationship between valuation and assessment as the disciplinary context for some reflections on individualism, relationship between the individual and the community, the personological foundation of subjectivity, freedom and personal/social responsibility in view of a different conception of territory, economy, economics.

The question of altruistic egoism, in the light of the relationship between efficiency and justice in the model of socio-economic development, introduces the debate on the two opposing and complementary concepts of freedom - negative and positive - outlining the limits and potential of liberal thought and the role of the individual as the original and primary bearer of the natural right to freedom. The recovery of the positive conception of liberty granting the independence of the personal axiologies introduces the fundamentals of the very nature of the person.

The phenomenology of the person provides elements of a conception that supports the territorial dialectic in terms of:

1. the spatial dimension (socio-economic and landscape) between entities endowed with their own personal identity, determined by the primary identification, and inseparable from the referents (communities of life) and from the circumstances of the formation and current layout of the urban centers that animate the territory and in which this personality is rooted;
2. the temporal dimension, in terms of the present responsibility that "secondary identification", self-constitutive of collective subjectivities, implies for the present, past and future self.

The potential to create novelty through persons flourishing in orderly communities that recognize their interconnectedness with the territory is the ultimate condition for the re-identification of people overcoming the introverted dimension of local egoism and welcoming the possibility of being "repopulated" by the landscape, the very essence of the territory.

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The Ancient Modernity of "The Line"

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Abstract. "The Line" stands as a visionary urban initiative, proposing a radical departure from traditional urban planning in the contemporary world. This paper explores the "ancient modernity" inherent in "The Line," a futuristic project set in Saudi Arabia, aiming to redefine the structure and essence of new planned settlements. Positioned as a groundbreaking example of reimagining urban living, "The Line" envisions a linear city where sustainability, technology, and quality of life converge harmoniously. Firstly, to assess the validity of this claim, the critical writings surrounding "The Line" and its historical references will be studied. The examination explores the motivations, design principles, and anticipated impacts of this self-claimed innovative endeavor, aiming to understand its potential to reshape the urban landscape and establish new standards for future city planning. By scrutinizing whether "The Line" represents a true paradigm shift in urban development, reflecting the aspirations and necessities of the modern world, this paper contributes insights into the project's significance and its potential to shape the future of urban planning. The synthesis of historical context and contemporary vision provides a nuanced perspective on the ancient modernity encapsulated in "The Line," highlighting its potentially transformative impact on the way we conceive and build cities.

Keywords: The Line · Saudi Arabia · Neom · Planned settlements

1 Introduction

The concept of the 'ideal city' has captivated the interest of various civilizations, particularly those that have achieved a certain level of development. It can be asserted that in every civilization, cities act as a gauge of attained success, offering tangible evidence of such achievements [1]. Once this acknowledgment is shared collectively, typically following the establishment of cities, it becomes possible to contemplate their true nature. The phenomenon of the city's reality becomes a subject for contemplation, sparking inquiries about its existence. The notion of an ideal city is inherent in the overall dynamics of human coexistence. In this context, the new Saudi city Neom, coined from a fusion of the Greek word for "new" and the Arabic term for "future," can undoubtedly be classified among those deemed "ideal." Neom comprises Oxagon, a reinterpretation of an industrial city, Trojena, a world-class ski destination, and The Line, situated in the desert region of the country's northwest, between the Red Sea and the borders with Egypt and Jordan. More recently, Neom saw the addition of projects included in the city resorts of the Gulf of Aqaba and Sindalah, a luxury destination in the Red Sea.

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Among Neom's components, "The Line" undoubtedly stands out as the proposal with the most significant visual and emotional impact and will be the focus of our critical discussion. Exploring this project's analysis from morphological and disciplinary perspectives is intriguing. We will observe how "The Line" is not as groundbreaking as it is portrayed and draws numerous criticisms from environmental, social, political, spatial, and mobility efficiency viewpoints. Suppose these criticisms have already been examined in the referenced texts. In that case, our text aims to provide an additional perspective, demonstrating that the modernist and deterministic approach to defining a newly established city is still robust. It remains unaffected by post-modernist thinking that had questioned the ability of the urban visions of modernist movement leaders to address the needs of their contemporary society and those of the future.

With the initiation of such urban phenomena, the new Middle Eastern hierarchies, particularly in the case of Saudi Crown Prince Mohammed bin Salman al-Saud, embarked on ambitious projects, aspiring to achieve unprecedented goals. Neom is a pivotal aspect of Vision 2030, which envisions a significant reduction in Saudi Arabia's reliance on oil and gas, aiming to decrease the current GDP share from 47% to 11% by the specified date. This objective aligns with the goal of increasing Saudi Arabia's population from the current 33 million to approximately 50–55 million by 2030 [2]. To realize this objective, among the various strategies proposed by the new Saudi leadership, establishing a city is planned, embodying, according to the designers, a plausible vision of an innovative and sustainable urban future. The project, known as "The Line," features two imposing and uninterrupted rows of skyscrapers designed to accommodate residential and functional spaces, spanning a length of 170 km, a width of 200 m, and a height of 500 m, surpassing any other building in Europe, Africa, and Latin America in size [3]. The twelve architecture firms unveiled as participants in this project, described by some as conceited, brutal, and implausible [4], rank among the most renowned in the world. They include some of the foremost contemporary architects, such as Pei Cobb Freed & Partners, Coop Himmelb(l)au, Tom Wiscombe Architecture, Peter Cook, Aedas, and initially, David Adjaye.

2 Advertising "The Line"

Since its announcement, the global media have extensively covered the desert city-line project, reaching a much broader audience than conventional digital platforms and specialized magazines. Even without specific data, it can be affirmed that the project has transcended industry circles and become public knowledge. This media presence aligns with the Saudi leadership's overarching strategy to modernize the country rapidly, moving away from its previous heavy reliance on oil resources. Architecture, particularly when spectacular, is utilized as a catalyst to attract foreign investments.

According to the authors' intentions, projects adopting the approach of "The Line" aim to represent potential future models—a genuine urban revolution. These futuristic communities settle in an environment devoid of roads, cars, and emissions, relying entirely on renewable energy. They prioritize people's health and well-being over transportation and infrastructure, deviating from the patterns observed in traditional cities. NEOM is designed to prioritize nature over development, with urban planning choices geared towards preserving 95% of its territory. Official communications emphasize an ideal year-round climate, ensuring residents can enjoy surrounding nature while walking. It seems that residents will have access to all amenities within a five-minute walk, and plans include a high-speed train connecting the two ends of the city in just 20 minutes [5]. According to the Saudi prince, the Saudis cannot ignore the livability and environmental crises afflicting the world's cities. NEOM is at the forefront of offering new and imaginative solutions to address these issues [6]. He added: "The Line will tackle the challenges of modern urban life and shed light on alternative ways of living [7]."

The designers propose a novel approach to urban design, known as zero-gravity urbanism, involving the vertical layering of city functions. This concept allows people to seamlessly move in three dimensions—up, down, or through—to access various amenities. Unlike simple tall buildings, this approach integrates public parks, pedestrian areas, schools, homes, and workplaces, facilitating effortless movement to meet daily needs within five minutes. "The Line," the kingdom asserts, will change the usual city experience, improve the work-life balance, enhance livability, and provide more free time for sports. Essentially, it envisions a vertical lifestyle, a next-generation architecture based on pedestrian communities and environmental solutions. Moreover, Joseph Bradley, Neom's chief technology officer, emphasizes, "It is not about building a smart city; it is about building the first cognitive city, where data and intelligence power world-class technology to interact with its population seamlessly [8]."

The project is promoted as a proposal to revolutionize the contemporary urban context. However, its advocates have often overlooked actual data that could validate or contradict such claims. Therefore, the following paragraph will delve into the main criticisms following the announcement and description of "The Line's" design features.

3 The Criticisms of the Project

Given the extensive media coverage, it is unsurprising that numerous critics have aimed to articulate their assessments of the features of "The Line." The ideas behind this project truly challenge the established norms of contemporary urban design. In an era where construction practices, particularly the redevelopment of modern cities, are undergoing sustainable reconsideration, "The Line" is positioned as a potential revolution in built environment philosophy. As we have observed, the rationale is straightforward: minimize the footprint to reduce land consumption significantly and, consequently, environmental impact. While the concept may appear legitimate, its spatial and methodological implementation methods give rise to more than one doubt. Criticism has been manifold and have spanned a diverse range of topics, which we will outline here (Fig. 1).

3.1 Political Argument

Numerous endeavors originating from Middle Eastern monarchies trigger reactions that decry alleged human rights violations. Here, we mention their existence solely for the sake of completeness. It is outside our purview to delve into these aspects in a paper concentrating on the architectural and urban prerogatives of the project at hand. Some

Fig. 1. "The Line" as depicted in the Neom web site

critics have underscored that the project involves the displacement of indigenous inhabitants and the ease with which the work proceeds without their consent. A portion of the site constitutes the home of the Huwaitat tribe, spanning Saudi Arabia, Jordan, and the Sinai Peninsula for generations, tracing their lineage before the establishment of the Saudi state. According to some journalists, at least 20,000 tribe members now face potential eviction due to the project, with no information on their future living arrangements [9]. The project's primary purpose is subject to political criticism, accused of catering exclusively to the affluent upper class, potentially expatriate professionals.

3.2 Mobility Argument

Even one of the ecological strengths of the project, the planned absence of vehicular traffic, is under scrutiny. "The Line," considered by some as the ideal ecologically friendly city in terms of mobility, faces criticism from researchers who illustrate why it should not be regarded as a model for future cities [10]. According to these researchers, the linear conception results in an extremely high population density, measuring ten times that of Manhattan and four times that of some districts in Manila, which are currently considered the most densely populated urban areas on Earth. This linear form, deemed ineffective by many, raises concerns about mobility efficiency. To achieve the planned total absence of cars and the complete pedestrianization of the urban complex, at least 86 stations may be required. However, even in this case, travel times would exceed the averages of other large cities of similar sizes [11].

Consequently, a super-fast subway is envisioned to connect one end to the other in just 20 min underground. Currently, no train in the world can achieve this—only the Hyperloop project could come close in performance. Questions should be raised about the impact of such infrastructures on the building regarding noise pollution and vibrations resulting from the continuous movement of subways. Therefore, unanswered questions remain. However, it is certain that the strategy, at least from a sustainability perspective, should be on the right track. After all, the footprint of a linear city compared to a conventional one is undoubtedly more minor. Since no cars are needed and everything is powered by renewable energy, the operation should be, in the end, highly ecological. However, research suggests that high density alone is insufficient to ensure optimal city mobility. In fact, a city cannot merely be considered a collection of isolated neighborhoods but requires that urban life opportunities be accessible beyond immediate proximity. Studies suggest that a circular form could address some of the challenges highlighted in the project by offering a shorter distance between people and greater access on foot [12]. Furthermore, it should be considered that an interruption on the line would paralyze the entire system. Indeed, a linear city's transport network makes it more nodal than linear. Finally, on foot and with other slow-moving vehicles, linearity can still be achieved but always on a significant scale. In essence, linearity would not work on a very small scale [13]. Although the goal in the linear city is for everyone to have an equal distance from its functions, the distances, in the end, are longer than those in compact cities.

3.3 Sustainability Argument

Despite the project's claims of high sustainability, it is surprising to discover measurements contradicting this assertion. According to Australian scientist Philip Oldfield, the construction of "The Line" alone would result in more than 1.8 billion tons of carbon dioxide emissions, surpassing the annual total emissions of the United Kingdom by over four times [14]. While the city's energy usage may be entirely renewable, the construction process involves substantial quantities that could be more sustainable. Additionally, many of the capital funds required for construction originate from something other than sustainable sources [15]. Another concern is the impact on local fauna, particularly migratory birds, which may face difficulties navigating around an enormous and insurmountable wall of mirrors, with easily imaginable consequences [16].

3.4 Originality Argument

One argument the promoters of "The Line" put forth is its purported originality. However, a deeper look at official Saudi presentations reveals that the city's concept could be more innovative than claimed. Linear urban areas existed long before the theoretical formulation of the linear city concept. The linear shape has been a fundamental aspect of defining urban territory since ancient times, with early human settlements often developing along linear features such as roads, coasts, or watercourses. According to Furundzic and Furundzic [17], the spontaneous nature of linear characteristics is often dictated by external factors like roads, rivers, or valleys that influence building conditions [17]. Roads, for instance, served as the backbone, facilitating all urban functions, including residence, production, storage, and trade.

The idea of developing cities exclusively along a single axis became possible only after the Industrial Revolution and the advent of the first mechanical means of transportation. Spanish engineer Arturo Soria y Mata pioneered the concept of a linear city by presenting "Ciudad Lineal" in 1882. Between 1892 and 1894, a project was initiated to construct a 55 km long linear city in a circular shape around Madrid, and a five-kilometer section was actually built [18]. The concept included a wide central avenue bordered by strips of buildings to facilitate both rail and road transportation of people and goods. This development extended into the countryside, encouraging agricultural production along the linear city and thereby improving overall living conditions. A similar idea was further explored by Edgar Chambless in the early 20th century in the United States. Chambless drew a straight line from the Atlantic to the Pacific on a map, passing through the Allegheny Mountains, the Mississippi River, and the Rocky Mountains. Along this line, he envisioned a continuous strip of two-story houses built on three railway lines, featuring a panoramic avenue on the roof and vast green areas. This infinite urban strip, named "Roadtown," aimed to blend the city's comforts with the beauty of the countryside [19]. While several proposals for linear cities were made, only a few were partially implemented, notably in the Soviet Union. The most radical avant-garde movements advocated abolishing traditional cities in favor of linear cities—however, a more moderate proposal by Professor N.A. Milyutin suggested the creation of industrial linear cities with populations ranging from 100,000 to 200,000 inhabitants. Milyutin's 1931 plan involved dividing the city's functions into parallel linear zones, akin to linear zoning. This approach allowed factory workers to move between residential and production areas. Even rural workers were intended to live in the residential area and commute by foot to adjacent farmland. Milyutin may have been aware of Arturo Soria y Mata's concept but was likely more influenced by Tony Garnier's "Cité Industrielle [20]."

The rejection of a centralized city as a typical expression of capitalism in favor of a strip city was proposed by constructivist theoretician Mikhail Okhitovich. In 1930, he presented a plan for the linear evolution of Magnitogorsk, imagining a network of eight vectors, each 25 km long, along which residents and workers would live in individual houses. Unfortunately, Okhitovich's idea was considered politically dangerous, leading to his execution in 1937 [21]. Even prominent figures of the modern movement, like Le Corbusier, proposed linear cities. In 1931, the French government presented an urban planning project for Algiers on the centenary of colonial rule. Le Corbusier envisioned the "Plan Obus," a futuristic infrastructure axis winding through the hills, containing 14 floors of housing for 180,000 workers under the overpass [21]. While none of the previously described proposals materialized, the idea continued to captivate urban planners and architects globally. In 1961, Kenzō Tange presented his vision for Tokyo Bay, featuring an urban spine stretching 80 km across the bay. Residential modules were connected by three levels of roads, rejoining the highway skeleton, forming a flexible system that could be expanded as needed. According to Tange's vision, the structure of the modern city would replace cathedrals, serving as the backbone of future metropolises [22]. In the same years, Peter Eisenman and Michael Graves, collaborating on various projects and competitions as Princeton University professors, proposed Linear City, becoming one of their most well-known projects. The continuous city extended along the East Coast, from Boston to Washington DC, covering a specific urban void of 22 miles in the state of New Jersey. Linear City envisioned two broad horizontal strips: one for industry and the other for residences, offices, and shops. Contemporaneously, the Italian group Superstudio proposed the "Continuous Monument," a critical warning against the unstoppable urbanization of the planet [23]. In 1969, the radical designers depicted the massive infrastructure surrounding the globe in a series of collages, imposing itself on both artificial and natural preexistences worldwide [24]. Comparing this project to "The Line," Kate Wagner noted how Superstudio's "Continuous Monument" served as a critique of capitalism: "The irony of all this would be delightful if it were not so sad" she said [25].

3.5 Critique of Modernity and Its Spatial Dimensions

After scrutinizing the key elements that many critics argue compromise the feasibility or, at the very least, the effectiveness of the urban and architectural proposal, we aim to direct our focus toward an aspect that we believe constitutes the original contribution of this paper to the project's analysis. In this context, we aim to explore what we perceive as a deterministic approach to shaping the urban concept. The two towering skyscrapers, each standing at 500 m, encapsulating an ideal world within and stretching parallel for the entire length of the city, create a closed system that is spatially impermeable. It is foreseeable that the designers developing their assigned sections interpret the perceptual transparency level concerning these physical limits. However, due to the nature of the project, physical interaction with the surrounding environment is either limited or entirely absent (Fig. 2).

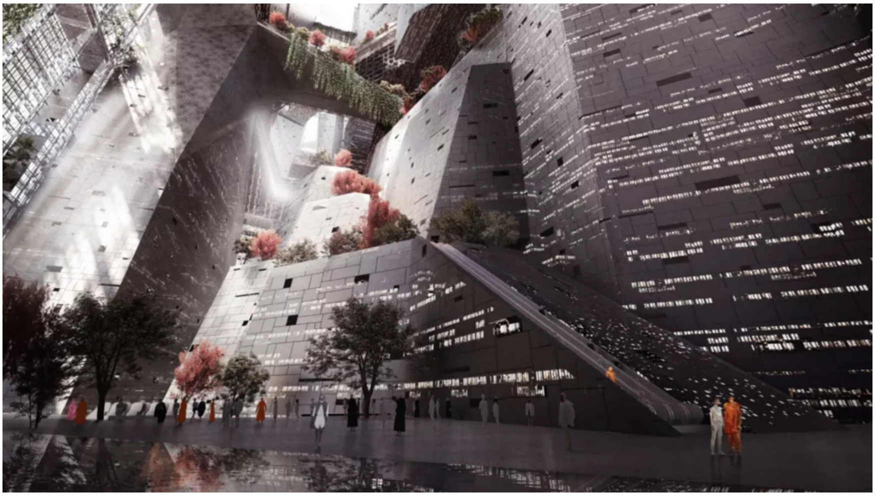

Fig. 2. The internal space of one of "The Line" sections (source: Neom website)

The mirrored surfaces reflecting the adjacent desert landscape offer a visual spectacle to an unidentified audience, given that the population will reside exclusively between the two vertical planes. This internal spatiality, well-described in terms of its environmental performances by the previously mentioned authors, seems to provide many innovative spatial solutions, at least as depicted in the renderings published alongside the project's publicity. Notably, these renderings predominantly capture the exact moment of the day: noon. This is the sole time of day when natural light can reach the lower levels of the space between the monumental continuous towers of the city. Naturally, one ponders about the level of natural illumination, especially on the lower floors of the buildings, during the rest of the day.

We introduce this example, questioning only one aspect related to the potential spatial quality of the project to delve into the theme of its modernity. Or, more accurately, its ancient modernity. A close observation of “The Line” brings to mind the proposals of architects and urban planners from the early 20th century. They advocated meticulously designed ideal cities down to the minutest detail—urban settlements where lifestyle and daily activities were envisaged in a design process aimed at defining new spatial arrangements and proposing “new men.” These were intended to be ideal societies of the future that would need to adapt their lifestyles to new housing models. History has almost consistently shown that such an approach has been unsuccessful. The notion that human prosperity can be realized through “better” design was the impetus behind the proposals of the modern movement. Despite good intentions, we now know the results were not entirely positive.

It is astonishing to witness some of the most renowned contemporary international architects reverting to such an antiquated design approach. Indeed, it is neither revolutionary nor futuristic, as the project’s propaganda asserts. It is not ancient because it lacks originality; instead, it is ancient because it is outdated. History has already demonstrated that the detailed design of urban models that do not allow modifications and adaptations over time by their inhabitants is destined to fail. The linear city can only expand at its ends [26]. In a minimal way, it can only accommodate the necessary variations and customizations to effectively and efficiently respond to the evolutions (or devolutions) of the society that will inhabit it.

4 Conclusion

The Crown Prince of Saudi Arabia, Mohammed bin Salman, has dispelled skepticism about “The Line” and emphasized his personal involvement in the design of the mega-city in a recent documentary titled “The Line: City of the Future in Saudi Arabia at Neom.” The Discovery Channel documentary features interviews with many members of the Neom team and the architects involved in the project. In his interview, the prince continued, “NEOM will be a place for people from all over the world to leave their mark on the world in creative and innovative ways. NEOM remains one of the most crucial projects of Saudi Vision 2030, and our commitment to delivering THE LINE on behalf of the nation remains unwavering [27].” In this paper, we intend to refrain from debating its possible (or impossible) constructability. After gathering information regarding the project’s criticisms, we aimed to analyze an aspect we consider strategic. We believe an urban operation aspiring to be indeed “revolutionary” must transcend previously experimented modernist positions. Considering the current state of the planet and the impending environmental challenges facing the global population, it is advisable to continue investing in the environmental, social, and spatial redevelopment of existing cities rather than succumb to the allure of spectacular yet ultimately simplistic models. After all, “there are thousands of cities in the world, and there is a reason none is in the shape of a line [28].”

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Green Spaces Accessibility in Historic Urban Centres

The Potential Role of Courtyards in the Case of Milan

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Abstract. Considering the fragility of urban systems in the face of increasing risks of climate change, one of the key issues in recent decades has been the adaptation of urban structures to achieve improved resilience. The integration of Green Infrastructures (GI) into the built environment plays a key role in this process as natural components can provide a more flexible and integrated answer to many stresses and challenges affecting urban areas. However, existing GI strategies are mostly based on large-scale interventions, such as greenways and new parks and they have major limitations when interfacing with compact urban fabrics. Focusing on the case study of Milan, this paper aims to relate urban structural metrics and design criteria of Urban Green Infrastructures (UGI), to identify possible synergies. In particular, the dimensions of Permeability and Porosity are assessed to evaluate the UGI planned by the PGT Milano 2030 in urban areas with different morphological characteristics. The results mark the incompatibility between the current UGI strategy and the characteristics of the historic centre. The study then focuses on the historic centre of Milan, with the objective of identifying its margins of transformability to re-integrate natural components even in this part of the city. The potential of inner courtyards and private urban voids for the integration of GI in the historic centre is assessed proposing a prioritisation and grouping of courtyards, based on the UGI connectivity principle, to optimise possible future interventions.

Keywords: Urban courtyards · Permeability · Urban Green Infrastructure

1 Introduction

It is now widely recognised that the fragility of urban systems in the face of unexpected risks and growing threats from climate change is related with the high level of anthropisation that makes the system rigid and scarcely resilient (Turner & Singer, 2014). For this reason, the Urban Green Infrastructure (UGI) is recognised as an effective tool to reintegrate natural elements and processes within the built environment to increase the system's flexibility and responsiveness to external and internal stimuli (EEA, 2015; Gill et al., 2007; Pauleit et al., 2017). The integration of UGI is realised in various ways

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and at different scales, from micro-interventions on existing buildings to the large-scale transformation of public open space. The latter category of interventions is the most significant in terms of the extent and benefits provided. Consequently, the possibility of consistently applying the UGI strategy and accessing related ecosystem services is constrained by the availability of transformable space and thus not equally distributed across the urban geography. In fact, the distribution across cities of urban elements and resources is often unbalanced with clear trends and patterns between city centres and more peripheral areas. Central areas use to have higher concentration of activities and services, better access to public transportation infrastructures, more job opportunities and higher market values (Schwarz, 2010). These advantages usually go with higher densities, having the counterbalance of limited void space and scarcity of green and natural spaces, negatively affecting health and environmental parameters. The high density also makes an obstacle for the continuity of the UGI, resulting in the exclusion of historic centres from re-naturing programs (Tzortzi & Lux, 2022). The city of Milan, with its radial structure, represents a perfect example of the difficulties brought by the morphology of historic compact cities and has been here taken as a case study to explore a potential approach integrating planning and design aspects.

This paper presents a morphological analysis of the city of Milan based on descriptive parameters from the urban porosity and permeability literature combined with green spaces accessibility to discuss and evaluate the need to differentiate UGI strategies according to the morphological specificities of the context. It moves from the observation of the current exclusion of the historic centre from greening plans (PGT Milano 2030). This underlines the inadequacy of existing green strategies in adapting to historic areas, usually lacking in green spaces. It was therefore chosen to analyse the system of urban voids and accessible spaces to clearly highlight the difference between the historic centre and more recently built neighbourhoods. This was coupled with an analysis of urban greenery, not only in terms of quantity but also in terms of accessibility by citizens. In conclusion, a strategy for the extension of the accessible space and greenery for the historic centre is proposed based on the inclusion of private courtyards in the network of accessible public spaces. A selection and prioritisation based on direct accessibility criteria was carried out with respect to all private courtyards. The outcome of the study shows the potential role of private space as a spatial focus for applying GI strategies in the historic centre.

2 Theoretical Framework

The theoretical framework of this paper is provided by the scientific literature about Urban Green Infrastructure (UGI), integrated with morphological studies aiming to characterise urban structures by the mean of spatial metrics, with the goal of defining potential criteria and strategies for supporting UGI implementation in historic contexts. Over the past decades, scientific research has produced several attempts to identify characteristics and principles for UGI planning (Young et al., 2014; Bartesaghi Koc et al., 2017; Pozoukidou, 2020). This paper refers to the seven principles identified by Pauleit et al. (2017), namely connectivity, multifunctionality, grey-green integration, multiscale, strategic, inter-/trans-disciplinary and socially inclusive. On the other hand, accepting the definition of cities as Complex Adaptive Systems (CAS), we had investigated several interdependent dimensions (e.g. Porosity, Permeability, Proximity, Accessibility etc.) via maps and metrics for a better understanding of urban structures and the interrelation of their components (Tadi et al., 2020). Given the importance of the void system for the implementation of UGI, main references have been found in studies explicitly focusing on the physical consistency of cities and the interaction between volumes and voids.

Biraghi et al. (2019) propose a cross-sectorial analogy between ground samples in hydraulics and figure-ground plans of cities, seen as sponge-like structures. The object of study of both disciplines presents a certain level of Porosity, meant as presence of void spaces (pores), and a certain level of Permeability, the extent to which those pores are connected allowing flow. In urban studies Permeability can be described as "the extent to which urban form permit or restrict movement of people, vehicles or material and immaterial flowing". In this perspective, streets are porous-permeable spaces while courts, a typical element of the Milanese morphology, are porous-non-permeable spaces, as building masses separate them from the streets. Combining the concept of permeability with the principles of UGIs, the continuity of the void space and the relationship with the built environment is significant for two main reasons:

- the physical location of the green network and the possibility of extending it in the future,
- the accessibility of the green network for people and thus the possibility of enjoying the ecosystem benefits.

Without claiming to be exhaustive of the possible spatial measures to be used in support of UGI planning, this study adopts two metrics, namely Street Area Ratio (SAR, Biraghi et al. 2019) and Net Courts Area Ratio (CTAR_N, Biraghi 2019) to drive the identification of those areas where it's actually complicated to implement UGI, but also where courts could play a strategic role to overcome these limits. SAR quantifies the portion of void space that is open, continuous, and accessible to urban flows (and potentially also to the expansion of green infrastructure). It is the ratio between total street area (As), and the total void area (Av), and ranges from 0 to 1.

$$\mathrm{SAR} = \mathrm{As}/\mathrm{AV} \tag{1}$$

CTAR_N quantifies the portion of void space internal to blocks specifically occupied by courts. It is the ratio between the total court area (Act) divided by the total void area inside the block, resulting from the difference between block area (Abl) and the area of buildings within it (Ab).

$$\mathrm{CTAR\_\ N} = \mathrm{Act}/(\mathrm{Abl} - \mathrm{Ab}) \tag{2}$$

3 Case Study: Milan, Italy

3.1 Green Strategies at the City Level

Looking at the distribution of existing green areas, it is evident how the percentage of green increases going from the centre to the periphery. The central area has two large parks (Parco Sempione and Giardini Montanelli) but lacks a capillary and widespread green network. As far as UGI's future development plans are concerned, the current Land Management Plan (PGT Milano 2030) aims precisely to thicken the existing network, to strengthen the ecological continuity between the city and the extra-urban natural system. To this purpose, it envisages the extension of the existing GI essentially through the transformation of former railway stations into urban parks and the transformation of major traffic roads into green axes (Fig. 1). These two actions, however, require large, continuous, and transformable void spaces and thus, for morphological reasons, are only applicable in post-industrial urban areas, completely excluding the pre-industrial city. The strategies implemented so far by the Municipality of Milan are fully consistent with the principle of UGI connectivity but have limited applicability. In fact, it is necessary to differentiate the way UGIs are applied according to Urban Morphological Types (UMTs), discussing on a case-by-case basis how to remain consistent with the principles initially identified (Gill et al., 2007). In this regard, the link between the connectivity of UGIs and the parameter of urban permeability appears significant.

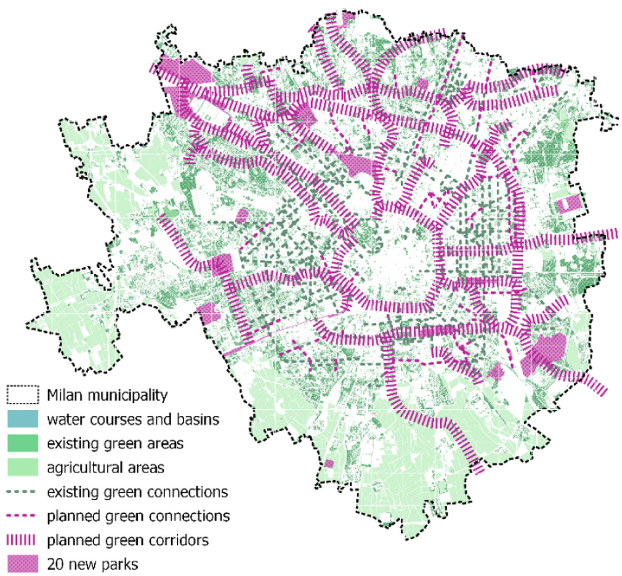

Fig. 1. Existing and planned Green Infrastructure in Milan municipality (data sources: DBT 2020, PGT Milano 2030)

For the urban permeability analyses, three main urban systems have been considered, namely the street network, the green network, and the system of urban courtyards (Fig. 2, left column). The recently updated database from the DBT2020 of the Lombardy Region was used. In particular, the following layers have been used: A020102 and A020106 to identify the built areas; A010101 (car street), A010102 (pedestrian paths) - A010103 (bike lanes) - A010104 (road) to identify the road network; A060401 to identify green areas and A020206 for the courtyards.

As shown by the three thematic classification maps (Fig. 2, right column) the proportion between the areas occupied by streets, green and courts changes across the city. The

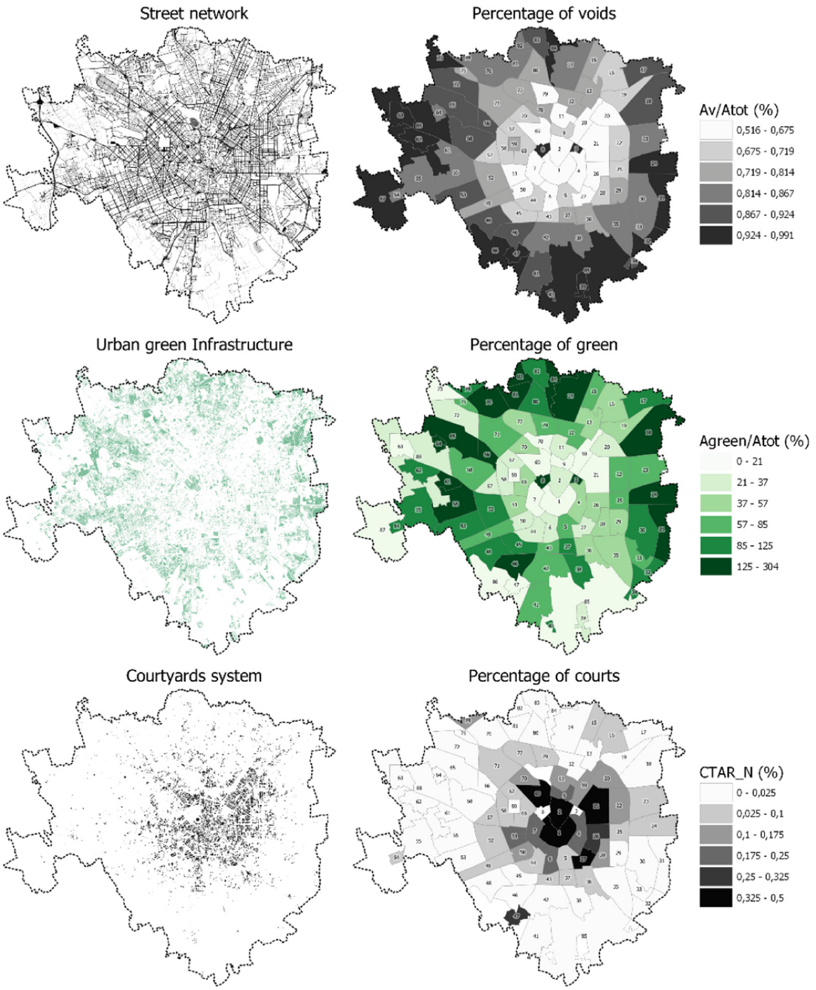

Fig. 2. Left column from the top: urban systems included in the permeability analysis. Right column from the top: classification of the NILs of Milan according to: the percentage of voids; the percentage of green areas; the relevance of courtyards expressed by the CTAR_N metric (data sources: DBT 2020, SIT Milano - Schede dei NIL).

first one shows the percentage of empty space over the total area of the NIL, the second presents the rate of green areas over the total and the last one is a visualization of the CTAR_N, which evaluates the relevance of courtyards. As can be observed, the trend in all maps respects the radial and concentric nature of Milan and the results are complementary. For instance, central districts resulted to be the most densely built and among those with least green spaces (regardless of their accessibility). The role of courtyards emerges as relevant in central districts. This means that out of the limited amount of unbuilt space, a relatively high percentage is already accessible and is mainly occupied by the road and path network. From the point of view of UGI planning, this observation confirms the difficulty of finding void spaces in the historic centre to convert into green areas and the transformation of linear connections also appears difficult.

3.2 The Historic Centre

Based on the considerations made so far, we can state that there is an incompatibility between the morphological characteristics of the historic centre and the current application of UGI. A closer look at the centre provides further confirmation. Out of the limited void space, more than half is occupied by the road and path network. Given the density of construction and the characteristics of the road network in this area, it appears particularly difficult to hypothesise the transformation of the road areas, a part of drastic solutions such as the total closure of the centre to traffic as occurred in other European cities (Topp & Pharoah, 1994). The remaining void space is equally divided between green areas (according to the DBT2020 classification) and internal courtyards or other private spaces. This figure already brings some attention to the role of courtyards and private spaces, which are to date the most uncertain and potentially transformable component of the void space.

Consequently, the key problem of the historic centre can be expressed in two ways: in terms of urban permeability, it can be reconfigured as the need to make the little existing void space more connected, and in terms of green infrastructure as the need to make more accessible the existing one and find new spaces to extend it. Inner courtyards are relevant from both perspectives, so the following section attempts to quantify their relevance and suggest possible ways of intervention.

The role of courtyards in the urban permeability map needs to be further assessed considering the morphological characteristics of these spaces. In fact, inner courtyards are void areas bordered by buildings on all sides (porous spaces), that in most cases are non-interconnected between each other nor with the street system (non-permeable spaces). With respect to these general considerations, however, it is necessary to further investigate the real modes of access to these spaces. Two types of access can be identified:

- semi-direct access, i.e. courtyards with vehicular passages at street level;
- indirect access, i.e. courtyards accessible passing through the private building.

The courtyards falling into the second category, with indirect access, are excessively distant from the system of public permeability and the need to pass through the private building to access them represents an obstacle (due to security, control, and other problems) that is difficult to overcome. The first category, on the other hand, represents the most exploitable margin of flexibility. Spaces with semi-direct access are already a natural extension of the street area, and the filters of access control and protection of private security are in most cases retracted or repeated within the courtyard. In Fig. 3, the SAR metric has been calculated on the city centre and associated with the calculation of the portion of accessible green areas (AGA). The first calculation considers only the street network in the accessible area ($SAR_1 = 53\%$). In the second case, green areas are added in the accessible areas, with a slight increase in SAR (60%) and a corresponding AGA percentage of 53%. Last, the third map adds semi-direct access courtyards to the permeability map. In this case, there is a further significant increase both in SAR (84%) and in the AGA (87%).

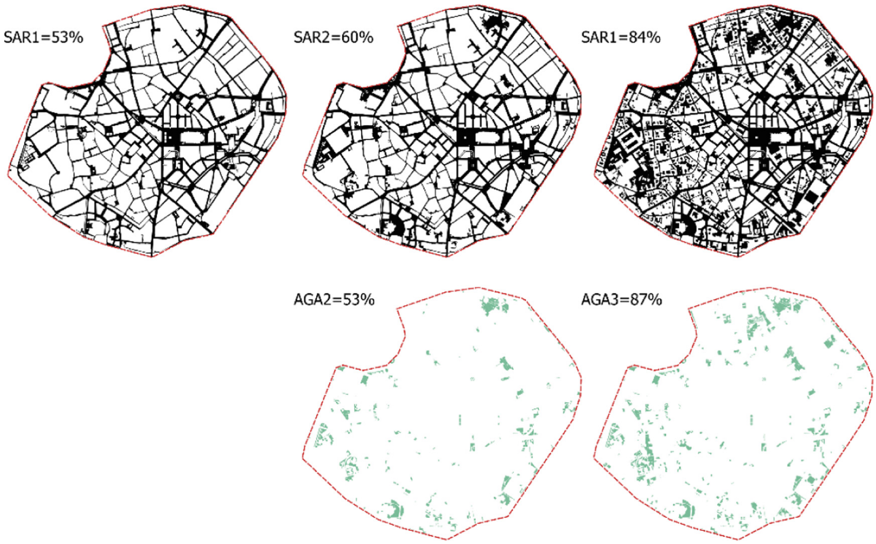

Fig. 3. First row: Street Area Ratio of the historic centre calculated as $SAR_1 = As_1/Av$; $SAR_2 = As_2/Av$ and $SA_3 = As_3/Av$; second row: Accessible Green Area (AGA) corresponding to SA_2 and SA_3

Analytic results are reported in Table 1. This analysis clearly shows the impact of the inclusion of courtyards in both previously mentioned respects, i.e. both in expanding accessible space in a very densely built-up urban area and in improving the accessibility of existing greenery. The possibility of future extension of UGI into private spaces needs to be further evaluated. The transversal approach between urban performances and UGI can support a selection and prioritisation of possible transformation interventions.

Table 1. Data sources and results of the SAR and AGA calculations

	Layers from DBT2020	Area (sqm)	SAR (%)	Agreen (sqm)	AGA (%)
Atot		2675532			
Ab	A020102	1341830			
Av	*Atot-Ab*	1314606		190111	100
As_1	A010101 A010102 A010103 A010104	693005	53	0	0
As_2	As_1 layers A060401	790840	60	100744	53
As_3	As_2 layers A020206	1109989	84	164601	87

Out of the 1531 courtyards in the study area, the selection of the semi-direct access class makes it possible to reduce the number of courtyards of interest to 283. A further rationalisation can be made by referring to the principle of UGI connectivity. In fact, where there is no real physical continuity of the green network, the vegetated patches should at least have a certain proximity and density so that they do not remain isolated and disconnected elements (Forman & Godron, 1986; Gill et al., 2007). Density heatmaps were used to detect more specific areas of interest in accordance to the above-mentioned criteria (Fig. 4): the first map (a), including all the existing courtyards, shows a certain homogeneity and it is difficult to clearly identify focuses of relevance, while limiting the analyses only to courtyards with semi-direct access (b) makes it possible to identify one major area and two additional spots with a higher concentration of courtyards to be potentially exploited.

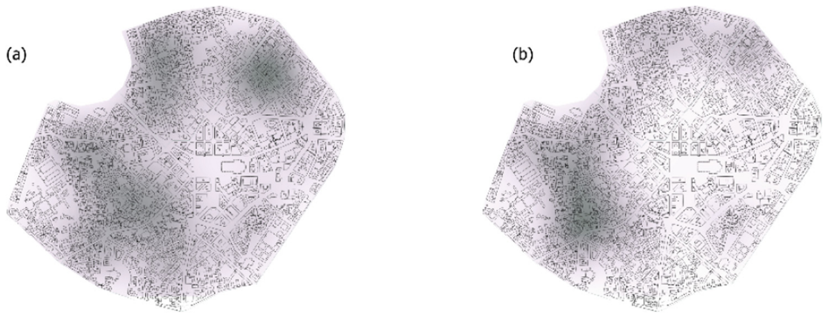

Fig. 4. Density of courtyards calculated considering all 1531 courtyards in the area (a) and only the 283 courtyards with semi-direct access (b).

To refine the assessment, a DBSCAN clustering (Ester et al., 1996) was carried out by setting the minimum number of elements per cluster at 20 courtyards and the maximum distance between elements at 180 m. Figure 5 shows the identification of 3 clusters. The selected courtyards are those from which transformation interventions could be started to include these private spaces in the urban green network from the point of view of both urban performance and usability. The parameters set are aimed at identifying clusters of courtyards that are sufficiently numerous to guarantee a significant intervention area and sufficiently close to remain within a comfortable walking distance for all. Possible interventions for improving the environmental performances consist in the depaving of portions of soil, the planting of vegetation on the ground or the application of green façade solutions on buildings, the disconnection of downspouts to relieve the centralised drainage system and encourage local infiltration processes; while as far as use is concerned, it is a matter of modifying the current uses of the space, reducing the areas for parking in favour of spaces for people and sociality, regulating use through defined hours for the non-resident public, rethinking ground floor activities or considering temporary uses and working on communication. The transformation of the courtyards in this sense would allow the urban green infrastructure, shown in Fig. 1 in its existing and planned components, to enter the dense urban fabric of the historic centre in an appropriate and necessarily different way respect to other urban areas.

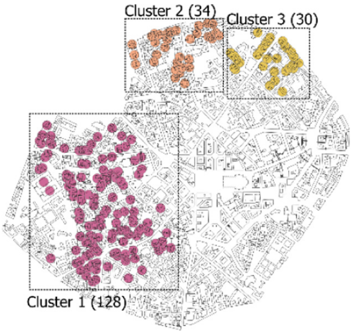

Fig. 5. Clusters of courtyards selected by numerosity (min 20) and proximity (max 180 m).

4 Conclusions

This research has revealed the potential synergy between UGI and morphological analyses for understanding the limitations approached from a more analytical point of view. In the case study presented, this approach has led to the identification of a way to extend the UGI in historic centres. The high data quality of the newly released DBT were exploited. However, such a detailed mapping of void spaces is not widespread. The main technical limitation of this study essentially concerned the availability of data. It is therefore difficult to imagine the extension of the study to other urban contexts due to the difficulty of finding data and the need of integrating with on field mapping. Another issue for its replicability in different morphologies could be the detection of enclosed void spaces as open courtyards, normally excluded from existing datasets and harder to be automatically derived via geoprocessing operations, but with an even higher potential in terms of potential connectivity. Additional synergies between the two considered domains could be explored in the future.

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Centre Versus Periphery. Territorial Imbalance from Perspectives of the Multiple Capital Dimensions

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Abstract. The concentration of populations, functions, services, infrastructures, technologies, and knowledge in coastal or urbanised areas to the detriment of rural and/or inner areas has led to a strong polarisation of values towards the former and depletion in the latter, generating strong asymmetries. The need to identify a new development process capable of interconnecting abandoned and marginalised areas with dense, attractive, and congested ones responds to the need for a rebalancing necessary to improve the overall functioning of the territorial system. This study proposes from the perspective of an axiological approach to the territory, an analysis model aimed at highlighting the relationships and oppositions between urban areas (Centre) and peripheries (Inner areas). The proposed methodological approach was based on the estimation of aggregate indices of the territorial capital forms. The estimation of the aggregate indices provides a measure of the asymmetries in terms of the value of the territorial capital forms and offers a knowledge base on which to improve or develop policies and actions aimed at rebalancing the territory. The estimation of the indices and their mapping has showed forms of polarisation between "Central" and "Inner areas" in the Sicilian territory.

Keywords: Axiological approach · Inner areas · Aggregated index

1 Introduction

The concentration of populations, functions, services, infrastructures, technologies, and knowledge in coastal or urbanised areas to the detriment of rural and/or inner areas has led to a strong polarisation of values towards the former and depletion in the latter, generating strong asymmetries.

The economic crises related to the COVID-19 Pandemic, the Russian-Ukrainian conflict, the Israeli-Palestinian conflict, and most recently, those related to the reprisals of the Houthi fighters in Yemen for control of the Red Sea, are generating socio-economic uncertainty and instability. Fragile and marginal territories that had already been affected by a progressive increase in social, material, economic, infrastructural vulnerability,

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being more exposed to external shocks, risk a rapid aggravation of their weak condition that could definitively compromise their destiny [1].

Numerous measures have been proposed at international and national level to limit this risk.

The 2030 Agenda promoted the development of a growing awareness about the urgency of addressing the issue of marginal areas at risk of abandonment, identifying measures to counter it such as Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable and in particular with reference to targets 11.1, 11.2, 11.4, 11.6, 11.a and 11.c [2].

The European Commission for the Revitalisation of Marginalised Areas has proposed "Europe 2020: The European Union Strategy for Growth and Job" [3] to promote "smart, sustainable and inclusive growth"; the Rural Vision [4] an initiative that creates a new momentum for rural areas, home to 30% of the EU population, based on the EU's green and digital transitions, and on lessons learned from the experience of the effects of the COVID-19 pandemic.

In Italy, the Agency for Territorial Cohesion has promoted the National Strategy for Inner Areas (NSIA), which provides support measures for those territories that have been affected by structural processes of depopulation and abandonment (1077 Italian municipalities and just over 2 million inhabitants), i.e. Fragile Territories. [5] The Italian National Recovery and Resilience Plan (PNRR) funded by the European Union—NextGeneration EU, with reference to the implementation of Mission No. 5 "Inclusion and Cohesion" [6] has provided funding of 100–400 million euro from the Fund for Development and Cohesion (FSC) for "special interventions for territorial cohesion", the "National Strategy for Inner Areas", the "Strengthening of services" and "community social infrastructure". To date, however, despite an increased awareness about the issue of marginal areas and the phenomenon of abandonment, the measures taken have been slow to produce the desired results [7]. The need to identify a new development process capable of interconnecting abandoned and marginalised areas with dense, attractive and congested ones responds to the need for a rebalancing necessary to improve the overall functioning of the territorial system.

In fact, urban areas, strong, dominant, catalysts of flows of "matter (natural resources), energy (labour) and information (technology)" have progressively extracted them from weak areas, transforming them into an environment in the Luhmanian sense [8], i.e. as a dominated and ousted element of the urban and territorial system. Now, they need, in order to improve their internal resilience, to integrate them for at least two reasons, because new flows will have to support their development and because they will have to manage their carrying capacity [9].

Weak areas characterised by the under-utilisation of human, natural, historical, and cultural heritage, and in most cases by weak local economies, have undergone a gradual and inexorable debasement of populations, functions, and values [10]. The causes of this debasement are to be found in the ineffectiveness of certain policies, such as: the reduction of health and education services; the lack of support for businesses from which the labour supply capable of allocating the population and retaining them in their places of birth should arise; the lack of investment to support mobility and transport, and the digital device or the absence of a systemic vision of the territorial issue.

If properly integrated, the heritage of weak areas can become a resource, an opportunity for the entire territorial system.

An action aimed at reversing the gradual process of disaffection into affection could generate the creation of a network or a territorial system capable of increasing the competitiveness of weak areas and removing urban asymmetries, favouring a rebalancing of territorial values [11].

The objective of this research is to explore from an axiological perspective the relations and oppositions between urban areas (Centre) and peripheries (Inner areas), highlighting and mapping the asymmetries in the values of the different forms of territorial capital based on the estimation of the aggregate indices [12]. The research focuses on the case study of the Sicilian territory. In this research, the NSIA classification was used as the fact-finding basis for the analysis of the Centre and Inner Areas.

2 Material

The National Strategy for Inner Areas classifies Italian municipalities based on the criterion of peripherality which is evaluated based on the level of access to essential services (health, education, mobility) [5].

The municipalities are classified with reference to the one identified as the “Pole”. The “Pole” municipality is the one that offers at the same time (alone or together with its neighbours) the following services: (1) Higher education—an upper secondary school offer (i.e. at least one high school—scientific or classical—and at least one between technical and vocational institute); (2) Health services—at least one hospital with a Level I D.E.A. (Department of Emergency and Acceptance); (3) Rail transport services—a railway station at least of the silver type, corresponding to medium-small facilities.

The municipalities based on distance from the “Pole” are classified into Centre and Inner Areas. The latter based on different levels of peripherality are classified as “Belt”, “Intermediate”, “Peripheral” and “Ultra-peripheral”. A mapping of the NSIA classification for municipalities in Sicily shows the distribution of the different types of areas in the regional territory (Fig. 1).

3 Method

The analysis aimed at exploring the relations and oppositions between urban areas (Centre) and peripheries (Inner areas) in order to highlight the asymmetries in the values of the different forms of capital [13] for the entire Sicilian territory is structured in the following phases:

- Identification of the forms of territorial capital;
- Construction of a geo-database of indicators characterising the forms of territorial capital;
- Construction of an aggregate index for the evaluation of the level of territorial capital [14]:

$$I_{C_i} = \sum_{i=1}^{k} w_{ij} x_{ij} \tag{1}$$

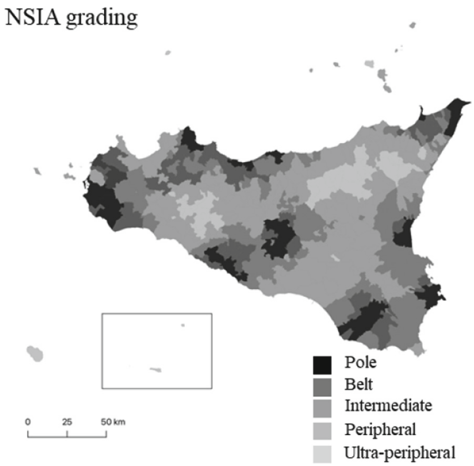

Fig. 1. Mapping of Sicilian municipalities according to the NSIA classification

- Where x_{ij} represent the values of the $j - th$ indicators of the $i - thC_i$ e w_{ij}
- Represent the relative weights.
- Identification of the weight system w_{ij} using the Entropy Weight Method (EWM) [15].
- Mapping in QGis of the aggregate indices of the $i - thC_i$ forms of territorial capital.

4 Results

In this study, we selected the following forms of territorial capital: human capital (*HC*), urban capital (*UC*), infrastructure capital (*IC*), economic capital (*EC*), natural capital (*NC*) and environmental capital (*EnC*) [5].

With reference to two main databases, namely that of the Agency for Territorial Cohesion [16] and that of the Council of Ministers [17] 162 indicators were selected, 13 for human capital (*HC*), 26 for urban capital (*UC*), 75 for infrastructure capital (*IC*), 30 for economic capital (*EC*), 5 for natural capital (*NC*) and 13 for environmental capital (*EnC*).

The indicators highlighted in Fig. 2 and Fig. 3 were selected for the capital forms *HC*,*UC*, *IC, EC, NC and EnC*.

For each indicator of the specific form of capital, the relative weights w_{ij} were estimated using the Entropy Weight Method (EWM).

With reference to the formula in Eq. 1, for each $i - thC_i$ territorial capital, the relative aggregate index was estimated, which is designed to show its level for each Sicilian municipality.

Figure 4 shows the maps of the 6 aggregated indices I_{C_H}, I_{C_U}, I_{C_I}, I_{C_E}, I_{C_N}, and $I_{C_{En}}$ for the different Sicilian municipalities.

The map for the I_{C_H} indicator shows a greater concentration of its value in the municipalities in the coastal areas of southern Sicily which, with reference to the NSIA classification are mostly identified as centre areas; in the cities of Siracusa, Catania and

Human capital

HC_1 – Residential population
HC_2 – Population density
HC_3 – Average annual rate of change of resident population
HC_4 – Old-age index
HC_5 – Percentage of foreign population
HC_6 – Incidence of young single-parent families
HC_7 – Incidence of young couples with children
HC_8 – Early exit from the education and training system
HC_9 – Incidence of lone elderly persons
HC_{10} – Incidence of mixed couples
HC_{11} – Share of pupils at risk of dropping out of secondary school
HC_{12} – Share of pupils at risk of dropping out of lower secondary schools
HC_{13} – Italian/foreigner school attendance ratio

Urban capital

UC_1 – Variation in the building underutilisation rate
UC_2 – Variation in the underutilisation index of dwellings
UC_3 – Variation in the under-utilisation rate of dwellings in built-up areas
UC_4 – Index of dwelling dispersion
UC_5 – Index of concentration of building use types
UC_6 – Index of compactness of urban areas
UC_7 – Urban landscape fragmentation index
UC_8 – Under-use of dwellings index
UC_9 – Fixed-site retail trade density
UC_{10} – Index of building expansion in urban centres and settlements
UC_{11} – Residential attractiveness index
UC_{12} – Residential mobility
UC_{13} – Population incidence in crowded conditions
UC_{14} – Housing crowding index
UC_{15} – Rate of building vacancy
UC_{16} – Drop-out rate of dwellings in built-up areas
UC_{17} – Housing exclusion index
UC_{18} – Incidence of residential buildings in a poor state of repair
UC_{19} – Index of availability of services in the dwelling
UC_{20} – Average age of recent housing stock
UC_{21} – Percentage of cars with low environmental impact
UC_{22} – Net human density
UC_{23} – Incidence of population living in cores and scattered dwellings
UC_{24} – Average real estate rent
UC_{25} – Average real estate value
UC_{26} – Urban (non-agricultural) green area per capita

Natural capital

NC_1 – Area covered by forest
NC_2 – Percentage of forest area
NC_3 – Percentage of municipal protected area
NC_4 – Presence or absence of Natura 2000 network (Sic/ZPS/ZSC)
NC_5 – Average agricultural value.

Economic capital

EC_1 – Total Employment in Local Units in the Municipality
EC_2 – Manufacturing employment at Local Units in the municipality
EC_3 – Tourism employment in the local units of the municipality
EC_4 – Manufacturing Sector Employment in Local Units
EC_5 – Employment in tourism sector in local units
EC_6 – Population employed in agriculture in 2001
EC_7 – Utilised agricultural area by location of the enterprise centre
EC_8 – Share of manufacturing employment in local units in the municipality
EC_9 – Share of tourism employment in the local units of the commune
EC_{10} – % change in manufacturing employment between 1971 and 2001
EC_{11} – % change in employment in the service sector between 1971 and 2001
EC_{12} – % change in population employed in agriculture between 1971 and 2001
EC_{13} – % change in utilised agricultural area by location of farm centre
EC_{14} – Herfindahl-Hirschman concentration index
EC_{15} – Change in economic dynamism index
EC_{16} – Employment rate
EC_{17} – Employment turnover index
EC_{18} – Change in unemployment rate
EC_{19} – Unemployment Rate
EC_{20} – Youth unemployment rate
EC_{21} – Incidence of young people out of the labour market and training
EC_{22} – Incidence of households with potential economic hardship
EC_{23} – Average income
EC_{24} – Gini index
EC_{25} – Italian/Foreign Employment Ratio
EC_{26} – Male/Female employment ratio
EC_{27} – Utilised Agricultural Area (UAA) as a percentage of total agricultural area
EC_{28} – Percentage of persons employed in ODA and KIBS enterprises
EC_{29} – Percentage of APS and KIBS enterprises
EC_{30} – Index of Economic Dynamism.

Environmental capital

EnC_1 – Seismic risk indicator
EnC_2 – Class of population exposed to landslide phenomena
EnC_3 – Standard deviation of altitudes
EnC_4 – Surface area of land consumed in areas of high and very high seismic hazard
EnC_5 – Percentage of municipal area at high and very high PAI landslide hazard
EnC_6 – Resident population at risk in areas of high and very high landslide hazard
EnC_7 – Surface area of soil consumed in areas with high and very high landslide hazard
EnC_8 – Percentage of municipal surface area at high hydraulic hazard
EnC_9 – Resident population at risk in areas of high hydraulic hazard
EnC_1 – Surface area of soil consumed in high hydraulic hazard areas
EnC_{10} – Total number of establishments with Major Accident Hazard
EnC_{12} – Soil consumed per capita
EnC_{13} – Municipal waste production per capita.

Fig. 2. Indicators of the territorial capital forms: *HC*,*UC*, *EC, NC* and *EnC*

Messina; in the coastal area of eastern Sicily; in the western and northwestern area of Sicily in the metropolitan area of Trapani and Palermo, in which a higher value of the indicator is still found for municipalities identified according to the NSIA classification as centre areas. The map for the I_{C_U} indicator shows a greater concentration of its value in the municipalities of the central and south-eastern areas of Sicily, many of which, are identified according to the NSIA classification as inland areas.

The map for the I_{C_I} indicator shows a greater concentration of its value in the municipalities in the Palermo and Catania metropolitan areas, highlighting a strong imbalance with the other metropolitan areas. The distribution of this index highlights a gap that should be filled. It is necessary to balance the endowment of facilities and services for Sicilian citizens, but also to support the development of productive activities and tourism. The map for the I_{C_E} indicator shows a greater concentration of its value in the municipalities in the southern, eastern, and western coastal areas of Sicily, in part of the Palermo and Messina metropolitan areas, and in some municipalities in of Enna and Caltanissetta metropolitan areas. The distribution of this index highlights the conditions of economic disadvantage in most municipalities in the central areas of Sicily. The map for the I_{C_N} indicator shows a greater concentration of its value in the municipalities of the eastern, south-eastern, and western coastal belts in the metropolitan areas of Palermo and Messina, in the Aeolian islands and Pantelleria. The $I_{C_{En}}$ indicator measures environmental risks (seismic risk, landslide and flood risk, industrial risk, soil

Infrastructural capital

IC_{M1} – Population mobility by private car
IC_{M2} – Daily mobility for study or work
IC_{M3} – Commuting index for work
IC_{M4} – Commuting index within the city
IC_{M5} – Index of road accessibility to commercial centres
IC_{M6} – Rail Accessibility Index
IC_{M7} – Index of accessibility to railway stations
IC_{M8} – Index of Mobility by Public Transport
IC_{M9} – Slow Mobility
IC_{S1} – University presence index
IC_{S2} – Composite accommodation function rate
IC_{S3} – Number of annual visitors to state places of culture
IC_{S4} – Number of State Places of Culture
IC_{S5} – Number of stadiums
IC_{S6} – Number of amusement and entertainment hubs
IC_{S7} – Number of commercial hubs
IC_{S8} – Number of ordinary hospital beds per 10,000 inhabitants
IC_{S9} – Index of dynamism of public institutions
IC_{S10} – Ordinary pharmacies per 10,000 inhabitants
IC_{S11} – Libraries per 10,000 inhabitants
IC_{S12} – Drinking water supplied to the municipal network per capita
IC_{S13} – Percentage of separate waste collection
IC_{S14} – Density of installed photovoltaic systems
IC_{S15} – Number of CNR institutes
IC_{S16} – Number of CNR sites
IC_{S17} –Number of locations of non-NRC research bodies and institutes
IC_{S18} – Number of science parks, technological districts and centres of excellence
IC_{S19} – Number of beds in hospital facilities
IC_{S20} – Number of hospitals
IC_{S21} – Number of hospitals with DEA
IC_{S22} – Number of elderly people enrolled in ASL of the municipality
IC_{S23} – Number of beds in residential facilities for the elderly
IC_{S24} – Number of kindergartens
IC_{S25} – Number of primary school
IC_{S26} – Number of secondary school
IC_{S27} – Number of secondary school
IC_{S28} – Number comprehensive school
IC_{S29} – Number Permanent Territorial Centre
IC_{S30} – Number of exhibition centres
IC_{S31} – Number of vocational colleges
IC_{S32} – Number of technical colleges
IC_{S33} – Number of higher education institutions
IC_{S34} – Number of educational establishments
IC_{S35} – Number of teacher training institutes
IC_{S36} – Number of Artistic Institutes
IC_{S37} – Number Classical High School
IC_{S38} – Number Scientific High School
IC_{S39} – Number Artistic High School
IC_{S40} – Number of Academies and Conservatories
IC_{S41} – Number of boarding schools and teacher training colleges
IC_{S42} – Number of Territorial Centres Pupils
IC_{S43} – Number of Vocational Colleges Pupils
IC_{S44} – Number of Technical Colleges Pupils
IC_{S45} – Number of Pupils at Comprehensive Institutions
IC_{S46} – Number of Pupils High Schools
IC_{S47} – Number of pupils at scientific high schools
IC_{S48} – Number of Pupils Kindergarten
IC_{S49} – Number of Primary School Pupils
IC_{S50} – Number of Secondary School Pupils
IC_{S51} – Number of pupils educational club
IC_{S52} – Number of pupils master school
IC_{S53} – Number of pupils art school
IC_{S54} – Number of pupils secondary school
IC_{S55} – Number of pupils artistic high school
IC_{S56} – Number of students in classical high school
IC_{S57} – Number of pupils academies and conservatorie
IC_{S58} – Number of pupils in boarding schools and educational establishments
IC_{T59} – Number of stations per municipality
IC_{T60} – Number of Platinum Type Station
IC_{T61} – Number of stations of type Gold
IC_{M62} – Number of stations of type
IC_{M63} – Number of stations of type Bronze
IC_{M64} – Share of population without fixed network broadband
IC_{M65} – Share of population without fixed-line and/or mobile broadband
IC_{M66} – Presence of a railway station of type at least Silver.

Fig. 3. Indicators of the infrastructural capital: *IC*

consumption and waste management). The map for the $I_{C_{En}}$ indicator shows a greater concentration of its value in the municipalities of the eastern-southern area, and in those fall in some portions of the coastal strips in the Palermo, Trapani, and Messina metropolitan areas.

5 Discussion

Based on the aggregate indices calculated for the different forms of territorial capital, the rankings of Sicilian municipalities were generated. The rankings show how the values of the different forms of territorial capital are distributed across the Sicilian territory, particularly with reference to the NSIA classification, between central and inner areas. The percentages of municipalities for the nine metropolitan areas of Sicily that fall into “Centre” areas according to the NSIA classification are: 28% for Agrigento (AG), 23% for Caltanissetta (CL), 45% for Catania (CT), 15% for Enna (EN), 17% for Messina (ME), 21% for Palermo (PA), 8% for Ragusa (RG), 19% for Siracusa (SR) and 54% for Trapani (TP). The metropolitan areas with the highest percentages of municipalities classified as “Centre” areas are therefore the metropolitan areas of Trapani and Catania. Most of these municipalities are coastal. The percentages of municipalities for the nine metropolitan areas of Sicily that fall under the NSIA classification of “Inner Areas” are: 72% for Agrigento (AG), 77% for Caltanissetta (CL), 55% for Catania (CT), 85% for Enna (EN), 83% for Messina (ME), 79% for Palermo (PA), 92% for Ragusa (RG), 81% for Siracusa (SR) and 46% for Trapani (TP).

The metropolitan areas with the highest percentages of municipalities classified as “Inner Areas” are therefore Ragusa, Enna, Messina, Trapani, and Palermo.

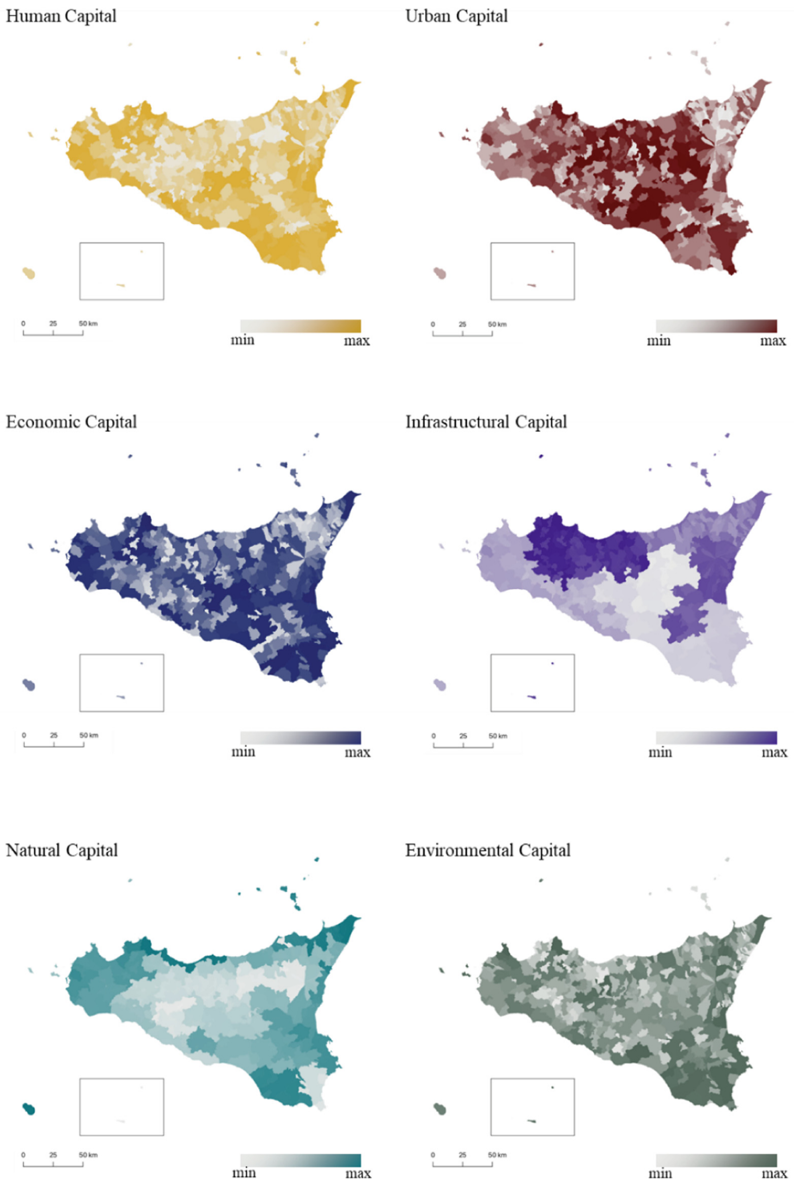

Fig. 4. Maps of the aggregate indices (I_{C_H}, I_{C_U}, I_{C_I}, I_{C_E}, I_{C_N}, and $I_{C_{En}}$) for Sicilian municipalities

As an example, we propose a comparison between the Centre and Inner areas with reference only to the aggregate index I_{C_E}. Table 1 shows the percentages of municipalities occupying the positions with respect to four ranges 1–100, 101–200, 201–300 and 301–390 of the ranking generated with reference to the aggregate index I_{C_E} and their classification according to NSIA:

Table 1. Comparisons between Sicilian "Centre" and "Inner Areas" based on index ranking I_{C_E}

	AG	CL	CT	EN	ME	PA	RG	SR	TR
CENTRE	28%	23%	45%	15%	17%	21%	8%	19%	54%
Ranking intervals									
1–100	5%	9%	40%	10%	6%	7%	8%	10%	33%
101–200	12%	5%	5%	0%	9%	13%	0%	0%	8%
201–300	5%	0%	0%	5%	2%	0%	0%	10%	8%
301–390	7%	9%	0%	0%	0%	0%	0%	0%	4%
INNER AREA	72%	77%	55%	85%	83%	79%	92%	81%	46%
Ranking intervals									
1–100	7%	18%	9%	35%	11%	7%	25%	38%	4%
101–200	14%	0%	12%	25%	12%	24%	33%	10%	29%
201–300	26%	32%	12%	25%	32%	22%	33%	29%	8%
301–390	26%	27%	22%	0%	28%	26%	0%	5%	4%

The metropolitan areas with the highest percentage of municipalities in the first range in order of intensity are Trapani and Catania for the "Centre" areas, and Enna and Siracusa for the "Inner Areas". In the first case, this positioning in the ranking confirms their characterisation according to NSIA as municipalities with the best economic profile and acting as attractors. In the second case, this positioning in the ranking does not confirm their characterisation according to NSIA, as they are municipalities with a better economic profile and are therefore less depressed than estimated in this classification. The metropolitan areas that have the highest percentage of municipalities in the last range in order of intensity are Messina, Caltanissetta, Agrigento, Palermo, and Catania for the "Inner Areas", highlighting their greater weakness in economic terms.

The municipalities of the Catania metropolitan area fall into two main clusters that highlight the economic polarisation of this territory. The first is the cluster of municipalities that fall in the first interval of the ranking and are "Centre" areas, mostly coastal or belonging to municipalities adjacent to that of Catania and which have the best positioning. The second is the cluster of municipalities that fall in the last interval of the ranking and are "Inner Areas", and which record the worst ranking.

The metropolitan area of Enna, which represents the geographic centre of Sicily, is characterised by municipalities that do not fall in the last range, both with reference to the Centre areas and with reference to the Inner Areas, highlighting that geographic marginality, in this case, is not matched by economic marginality. Overall, the poorest areas are those classified in "Inner Areas". In the second interval, the metropolitan areas with a weaker economic profile are, in order of severity Ragusa, Trapani, Enna, Palermo, Agrigento, Catania and Messina in a tied, and Siracusa. In this interval, no municipality in the Caltanissetta metropolitan area falls within it. In the third interval, the metropolitan areas with a weaker economic profile are, in order of severity, Messina, Caltanissetta, Palermo and Agrigento in a tied, Catania, and followed quite closely by Siracusa and Trapani. No municipalities in the Ragusa metropolitan area infall in the fourth interval.

6 Conclusion

In this study we proposed, from the perspective of an axiological approach to the territory, an analysis model aimed at highlighting the relationships and oppositions between urban areas (Centre) and peripheries (Inner areas). The proposed methodological approach was based on the estimation of aggregate indices of territorial capital forms (I_{C_H}, I_{C_U}, I_{C_I}, I_{C_E}, I_{C_N}, and $I_{C_{En}}$), calculated on the basis of a set of 162 indicators. The estimation of the aggregate indices provides a measure of the asymmetries in terms of the value of the forms of territorial capital. It also offers a knowledge base on which to improve or develop policies and actions aimed at rebalancing the territory. The analysis applied to the Sicilian case study has highlighted aspects relating to the vulnerability of many municipalities about human, economic and infrastructural capital, their exposure to environmental risks (seismic risk, landslide and flood risk, industrial risk, land consumption and waste management), and the spread of forms of underutilisation of urban and natural capital. The estimation of the indices and their mapping showed: a greater value of I_{C_H} in the municipalities in the coastal areas of southern Sicily; a greater value of I_{C_U} in the municipalities in the central and south-eastern areas of Sicily, many of which are classified as Inner areas; a greater value of I_{C_I} in the municipalities in the Palermo and Catania metropolitan areas, highlighting a strong imbalance with the other metropolitan areas; a greater value of I_{C_E} in the municipalities in the southern, eastern, western coastal areas of Sicily, in part in the Palermo and Messina metropolitan areas a greater value of I_{C_N} in the municipalities in the eastern, south-eastern, western coastal belts in the Palermo and Messina metropolitan areas, in the Aeolian islands and Pantelleria; a greater value of I_{C_N} in the municipalities in the eastern-southern area, of those falling in some portions in the coastal belts in the Palermo, Trapani and Messina metropolitan areas. The study, with reference to the I_{C_E} index, has highlighted: forms of polarisation and therefore of contrast between "Central" and "Inner areas" in the municipalities in the Catania metropolitan area; a strong economic marginalisation of many municipalities falling within the Internal Areas present in the last places of the ranking for the Messina, Caltanissetta, Agrigento, Palermo and Catania metropolitan areas; an overall assessment of the economic weakness of the municipalities falling within the Internal Areas for the Messina, Caltanissetta, Agrigento and Palermo metropolitan areas.

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Assessing Territorial Capabilities to Support Decision-Making: A Multi-sectoral and Cross-Scalar Governance Tool

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Abstract. Multi-sectoral and cross-scalar governance are essential for balancing development and sustainability among territories. Especially policies for fragile and peripheral territories require an overall understanding about different aspects that have an influence on their performances. Thus, the "Territorial Capital" is a key-concept that could help decision-makers understand and evaluate the current opportunities and challenges facing different territories and communities. In this paper we propose a tool for assessing various dimensions of territorial capital, including economic, sociocultural, infrastructural, and environmental elements. The different indicators and indices included in the tool are evaluated at the municipal scale and consider the existing interactions between territories that affect her capabilities. These data were implemented in a geographic information system (GIS) platform that allows users to analyze and visualize spatial and non-spatial data and information, and to obtain maps based on the Territorial Capital' indicators. This comprehensive and systematic methodology is especially (but not only) useful for selecting the most appropriate interventions for peripheral and fragile areas. Thus, we present a case study referring a selection of project areas defined by the Italian National Strategy for Inner Areas (SNAI). The results show strengths and limitations of this approach for guiding policies and actions.

Keywords: Inner Peripheries · Urban Systems · Territorial Capital · Integrated Evaluation

1 Introduction

The territory is a complex socio-economic and ecological system where multiple human, and natural processes interact across different temporal and spatial scales in intricate ways. Thus, changes in territorial organization and development patterns are related to a range of material and immaterial factors that contribute to human well-being.

According to this, strategies and measures must be based on these issues to be cost-effective in terms of achieving specified objectives. Considerable efforts have been made

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to develop methods and tools for evaluating the impacts of such issues and orient public policies and private efforts especially for supporting development in peripheral territories that are a "composite interdisciplinary problem" [1–3].

Among these, the European Union indicates the "Inner Peripheries" (IP) as strategic territories for an effective use of the EU Cohesion Policy funds [4]. IP are identified as areas situated at a great distance (lower accessibility) from the main centres of economic activities and essential services. Thus, the general quality of life can be perceived as poor compared to other territories [5–7]. Therefore, the identification and mapping of these areas do not consider other aspects that are pertinent in the integrated conception of territorial development such as ecological and productive characters. These aspects are included in the concept of the "Territorial Capital" that might help to combine different territorial assets (e.g. [8]). Our study aligns with this perspective with a focus on assessment tools for identifying, mapping, and managing development processes.

The proposed tool pinpoints eight primary realms for action (territorial sub-capitals): the human, social, cognitive, infrastructural, productive, relational, environmental, and settlement components. Together, these embody the developmental possibilities inherent in a specific territory [9, 10]. The selected indicators enable the evaluation of the territorial performance within each of these distinct domains. The method and the tool are applied within selected inner areas in the Sardinia Region (Italy). The results from the case studies demonstrate the tool's potential in assessing and comparing various aspects of territorial capital. It also indicates its capacity to propose suitable policies and intervention scenarios customized to the priorities of each territory, thereby promoting inclusive and balanced development.

The following section describes challenges encountered in measuring territorial peripherality and presents the suggested framework for evaluating territorial capital. This model provides the theoretical structure for understanding the methodologies applied in the assessment of territorial capital. The third part expounds on the analysis of a renowned composite indicator through a case study. The fourth part puts forth conclusions and offers recommendations for prospective research.

2 Measuring Peripherality and Territorial Capital

The issue of Territorial Capital (TC), as highlighted earlier, has garnered growing attention within academic and policy-making spheres in recent years. This heightened interest is attributed to the formidable challenge of formulating effective strategies to address the disparities and imbalances in living and working conditions across different territories.

Various methodologies, methods, techniques, and tools have been proposed to conduct a multi-criteria evaluation of TC, aiming to comprehensively grasp the diverse dimensions of territorial peripherality. The implementation of these approaches has proven crucial for gaining an in-depth understanding of the dynamics characterizing inner peripheral areas [11]. Camagni [12, 13], followed by Brasili [14], Fratesi and Perucca [15], Tóth [8], and other authors, emphasize the importance of considering a diverse array of indicators and parameters when evaluating to fully capture the complexity of territorial disparities. More recently, Benassi et al. [16] delved into the "meso dimension" of TC in 2021, focusing on the distinct resources and endowments of a territory that precede its performances, such as the intangible qualities of an area (e.g. cultural heritage).

Beyond the intrinsic value of local assets, their geographical location and relative spatial positioning wield significant influence over the territorial capital. The site-specific territorial capital extends its impact not only to the immediate users of a place but also to those in geographical proximity. This involves intricate connections and effects stemming from relationships, externalities, and spillover effects generated by such closeness and connectivity [17]. This 'given' and 'position' characteristics of the TC are acknowledged by the Italian Government in the "National Strategy for Inner Areas" (NSIA) 2014–2020, «one of the most comprehensive and integrated strategies for tackling the problems of depopulation and low access to services» [18]. Italy was among the first EU countries to devise a strategy explicitly tailored to bolster the development of "Inner Areas" (IA). These are regions distinguished by their distance from primary service centers, including education, health and mobility services [10, 19, 20].

Nevertheless, the more nuanced analysis of these territories proposed by the TC concept could reveal potentialities and strengths that the NSIA does not consider but are pertinent for shaping effective long-term development policies [21, 22]. While this concept is repeatedly mentioned in both the NSIA and the objectives of EU Policies [6, 23–26], it has yet to find concrete operationalization.

3 Calculating Composite Index: One Example

3.1 Methods and Data

To contribute to this field of research, we have developed an evaluation model that combines tangible and intangible assets shaping territorial capabilities. Drawing insights from existing literature and the characteristics of the regional context of Sardinia, we have identified eight categories of analysis and formulated 33 corresponding indicators (see Table 1) [9, 10, 27]. The assessment is applicable at the municipal scale, where a reliable open-access database is readily available.

The calculation procedure considers not only the intrinsic value of local assets within a given municipal territory but also the influence that the proximity of services can have on that territory. In this regard, the presence of services within a 20 km distance has been considered as positive, and therefore, it has an impact on the value of the final indicator. This consideration takes into account the actual routes of local public transportation.

The values of the indicators and indices for each sub-capital were normalized to give them a score range from 0 to 1. Finally, the eight indices were aggregated into a composite final index (Territorial Capital Index), calculated as the average of the indices for each sub-capital.

This methodology is integrated into a Geographic Information System (GIS) platform designed to be easy to use to calculation and result visualization. This not only enhances transparency in the evaluation process but also visually communicates the various aspects of territorial capital [28, 29].

Table 1. The eight categories of capitals and related indicators (Source: [9]).

1. HUMAN	5. PRODUCTIVE
1.1) Old-age Index; 1.2) Specific Employment Rate; 1.3) Education Index; 1.4) Migratory balance	5.1) Entrepreneurship Index; 5.2) Tourism Accommodation Capacity; 5.3) Start-up Companies; 5.4) Average Income
2. SOCIAL	6. RELATIONAL
2.1) Voting Population; 2.2) Voluntary Associations; 2.3) Expenditure for Social Services; 2.4) Socio-Educational Users	6.1) Public Funding; 6.2) University Students; 6.3) Bank Branches; 6.4) Business Networks
3. COGNITIVE	7. ENVIRONMENTAL
3.1) Cultural and Recreational services; 3.2) Expenditure for Culture; 3.3) Broadband Accessibility; 3.4) Social Promotion Associations	7.1) Parks and Protected Areas; 7.2) Utilized Agricultural Area; 7.3) Areas at Risk; 7.4) Waste sorting; 7.5) Sustainable Energy
4. INFRASTRUCTURAL	8. SETTLEMENT
4.1) Health Services; 4.2) Suburban Public Transport; 4.3) Postal Offices; 4.4) Police Stations	8.1) Uninhabited Housing; 8.2) Housing Quality; 8.3) Average age of buildings; 8.4) Average income from buildings

3.2 Case Study

The procedure has been applied to all the municipalities in the Sardinia region. Figure 1 shows the comparison between Inner Areas methodology and Territorial Capital evaluation (Fig. 1). In particular, the analysis presented in this paper pertains specifically to 45 municipalities, encompassed within the four project areas outlined by the NSIA (Fig. 2).

The NSIA 2014–2020, in fact, identify the Italian pilot areas to support strategies for both local development and service innovation by combining European Structural and Investment Funds and national finance [20, 30–32]. By the end of April 2017, a total of 72 pilot areas were selected and for the programming period 2021–2027, 56 new areas and 35 municipalities included in the 'Special Project Minor Islands' have been integrated into the Strategy. Among the areas included in the programming period 2014–2020, 37 areas are confirmed without any variation of the initial perimeter, while 30 present a new perimeter compared to the original configuration following the annexation and/or exclusion of municipalities. In total there are 124 project areas encompassing more than 1.900 municipalities and 4,5 million inhabitants.

The analysis presented in this paper pertains specifically to 45 municipalities, encompassed within the four project areas outlined by the NSIA. The Strategy, indeed, finances interventions in four networks of municipalities (A1. Alta Marmilla; A2. Gennargentu-Mandrolisai; A3. Barbagia; A4 Valle del Cedrino) and four municipalities

(M1. Sant'Antioco; M2. Carloforte; M3. Porto Torres; M4. La Maddalena) identified among the most vulnerable territories in Sardinia (see Fig. 2).

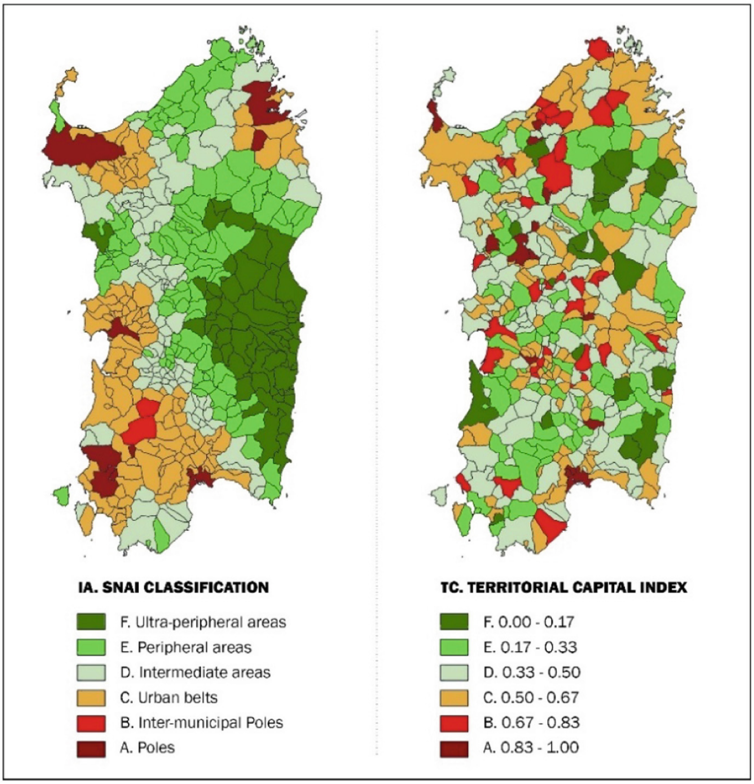

Fig. 1. Comparison between Inner Areas and Territorial Capital methodologies.

Among these, the areas of the Union of Municipalities "Alta Marmilla" (A1) and the Mountain Community "Gennargentu Mandrolisai" (A2) were already included in the programming for the 2014–2020 period, while the other six areas/municipalities were integrated into the new programming for 2021–2027, as per Deliberation no. 39/44 of July 30, 2020. Specifically, the four municipalities are all classified as peripheral and ultra-peripheral and are part of the special project "Minor Islands", to which a portion of the resources allocated to the NSIA has been dedicated (La Maddalena in its eponymous archipelago; Sant'Antioco, Calasetta, and Carloforte in the Sulcis Archipelago, and the municipality of Porto Torres in reference to the island of Asinara.

Table 2 and Fig. 3 provide data and show the results of the detailed analysis for the four areas A1-A4. The comparison between the classification carried out by the NSIA and the assessment conducted using the Territorial Capital-based methodology highlights significant differences. The framework presented by the proposed methodology reveals a greater articulation of the values assigned to various municipalities.

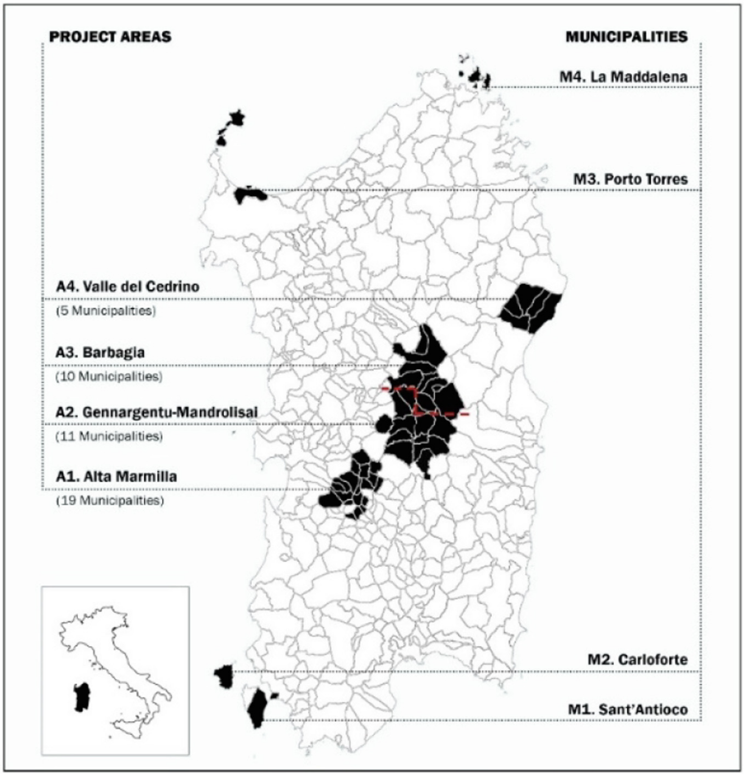

Fig. 2. Italian Inner Areas Strategy: project areas for the programming period 2021–2027). The A1 and A2 areas are in a more advanced stage compared to the other areas. Both these territories have already endorsed their area strategy and entered into the Framework Program Agreement, initiating the implementation phase for the immediately actionable interventions outlined in their respective agreements.

Table 2. Data of the four selected project areas (Istat 2019)**.**

Project Area	Number of Municipalities	Total Population	Surface (sq Km)	Demographic density (inh. per sq Km)
A1	19	8.413	325,69	27.29
A2	11	12.727	562,83	23,15
A3	10	15.422	534,07	32,51
A4	5	12.556	304,16	34,98

The analysis conducted reveals that, for some municipalities, there are significant discrepancies in the results assigned by the two assessments. In particular, nine municipalities receive a highly positive evaluation in our methodology, categorizing them as central areas (Table 3). This result is interesting because it highlights how certain areas considered peripheral by SNAI have values in specific sub-capitals that enhance their performance in certain aspects. These aspects represent the characteristics to preserve or improve to increase their attractiveness. The case of the municipality of Belvì located in project area A2 is particularly noteworthy in this regard.

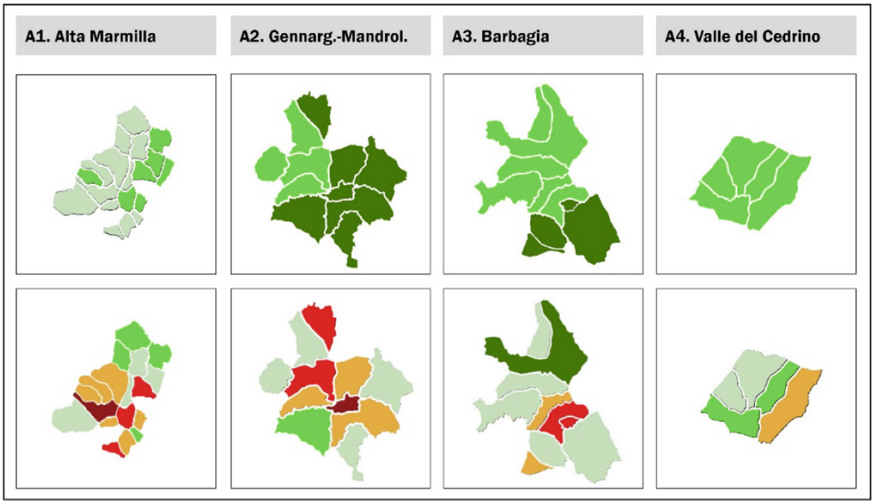

Fig. 3. Classification of the four project areas (A1-A4): comparison between Inner Areas and Territorial Capital methodologies.

Table 3. Data of the 9 municipalities (Istat 2023) included in A1-A4 project areas classified as "D", "peripheral (E)" and "ultra-peripheral (F)" by the NSIA that correspond to "A" and "B" categories in the TC evaluation.

PA	Municipality	IA	TC	Population	Surface (sq Km)	Demog. density (inh. per sq Km)
A1	Ales	D	A	1.267	22,45	56,43
A1	Assolo	E	B	342	16,37	20,89
A1	Gonnoscodina	D	B	433	8,82	49,09
A1	Gonnosnò	E	B	708	15,46	45,80
A2	Belvì	F	A	555	18,10	30,66
A2	Sorgono	E	B	1.491	56,05	26,60
A2	Teti	F	B	595	43,80	13,58
A3	Gavoi	E	B	2.488	38,06	65,37
A3	Lodine	F	B	305	7,70	39,61

The maximum score of Belvì is achieved in social capital, attributed to high spending on social services and a high number of volunteer associations operating in the municipal territory. Following closely is the infrastructural capital, calculated also in relation to the connection with the territory provided by public transportation.

Lower values are observed, on the other hand, in the settlement capital due to the state of preservation of the housing heritage, and in the productive capital, owing to the low average per capita income and the low number of active businesses and available beds for tourism. This information can be used in decision-making processes for a range of applications, including programming expenditure, urban planning, and administration.

4 Conclusions

The present study underscores the importance of evaluating territorial capital as a means to address regional disparities and promote balanced development. By adopting a multi-dimensional approach that considers economic, sociocultural, infrastructural, and environmental factors, we provide decision-makers with valuable insights into the opportunities and challenges facing different territories and communities. The integration of these insights into policymaking processes can lead to more effective and targeted interventions, particularly in peripheral and fragile areas.

The case study conducted in selected areas of Sardinia serves as a pertinent example of the utility of our methodology. Through the application of our assessment tool, we were able to identify specific strengths and weaknesses within these regions, shedding light on areas where targeted interventions could yield the greatest impact. Importantly, our analysis revealed discrepancies between traditional classifications of peripherality and the nuanced understanding provided by the territorial capital framework. For instance, certain municipalities classified as peripheral by existing strategies exhibited strengths in specific sub-capitals, suggesting untapped potential for development.

One noteworthy finding from our case study was the importance of social capital in shaping the resilience and vibrancy of communities. Municipalities with high levels of social capital, characterized by strong community ties and active participation in social activities, demonstrated greater potential for sustainable development. This highlights the need for policies that foster social cohesion and civic engagement as integral components of regional development strategies.

Furthermore, our analysis underscored the interconnectedness of different dimensions of territorial capital. For example, investments in infrastructure not only enhance connectivity and accessibility but also contribute to economic growth and social well-being. Recognizing these interdependencies is crucial for designing holistic and integrated development interventions that address the diverse needs of communities.

Looking ahead, it is imperative to continue refining methodologies for evaluating territorial capital and enhancing the applicability of these concepts in real-world contexts. Future research should explore innovative approaches for incorporating qualitative data and local knowledge into assessment frameworks, ensuring that they capture the complexities of regional dynamics. Additionally, greater collaboration between researchers, policymakers, and local stakeholders is essential to co-designing interventions that are responsive to the unique challenges and opportunities of each territory.

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Village Repopulation: Analysis of Extra-Economic Indicators to Evaluate and Valorise Social Generativity in Ecovillages

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Abstract. Along with continuous urban growth, a depopulation process has increasingly involved smaller settlements. Over 70% of Italian Municipalities have a population below 5,000 inhabitants, with some of them in a state of abandonment and several more at risk of abandonment. Due to the significant presence of cultural heritage and the need to rebalance territorial presence, several national and local initiatives, programs, and projects have been set up to improve living conditions in villages and support their repopulation. In some cases, these have led to virtuous practices and positive results in the contexts where they have been applied. In others, the abandonment dynamics have not been stopped despite structural and functional interventions. On the other hand, observing successful bottom-up repopulation initiatives has revealed a pattern associated with a different perspective on regeneration and the potential of villages. The analysis has shed light on spirituality-based and community-based lifestyles practised in several villages throughout Italy and beyond. This can represent a key to countering hamlets' abandonment by making them reservoirs where to experience an evolutionary lifestyle with a high level of social generativity. However, the indicators adopted in national programs do not allow valuing this component. Thus, this paper critically analyses the current and available indicators and suggests a potential integration.

Keywords: indicators · Inner Areas · ecovillage

1 Introduction

Among European countries, Italy has the highest share of "small towns" or villages, also known by the Italian word *borghi*. The condition of "small town" (It. *piccolo comune*) has been codified in the Italian legislative framework with Law 158/2017 [1], including all Italian municipalities with a population below 5,000 inhabitants. As of 2023, this category lists 5,533 Municipalities, which represent 69.85% of the total, with a total population of 10 million residents, equal to 17% of the Italian population. They are a key component of Italian cultural heritage, as they host 31.1% of cultural locations and 32.8% of museums [2].

This considerable number resulted from a vast and diffuse depopulation process that started at the beginning of the 20th century and dramatically intensified in the second

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post-war period for several reasons. The population involved in this centripetal movement from minor to major centres has reached a considerable entity, ranging around 900,000 people. Many villages have been wholly abandoned through this process, while many more are at risk of abandonment. The number of abandoned villages will surely increase at the next generational turn, as the average age of villages' population is growing progressively, with only 15.7% of inhabitants below 40 [3].

Due to the criticality of this issue and its large-scale effects on the territories, as it is counterpointed by a state of overcrowding and congestion in Italian centres, which consequently host the population that has left minor villages, the theme of village regeneration and repopulation has been at the centre of several national policies, among which the most relevant ones are the National Strategy for Inner Areas (NSIA) and the National Plan for Villages within the Italian National Recovery and Resilience Plan (NRRP), a plan of investments within the Next Generation-EU programme, with resources allocated to Italy by the European Union to implement reforms along the three axes of digitisation and innovation, ecological transition, and social inclusion.

Alongside national-scale initiatives, other typologies of projects are launched by local administrations, stakeholders, inhabitants, or former inhabitants to stem depopulation processes. These often draw a village's identity and memory, driven by the will to keep residing in their village or to restore habitability in an abandoned one damaged by a destructive event.

Finally, cases of bottom-up repopulation also sometimes occur: that is, an entirely new community settles in an abandoned village, establishing a new lifestyle and exploiting the village's liveability potential differently, relying on its opportunities for spirituality and collective social life, serving as pivots for the generation of new, spontaneous territorial flows around such centres.

The work described in this paper focuses on analysing the indicators used in Italian policies to evaluate the interventions in villages and the choice of funding allocation. The main research question is whether the indicators in place can cover this wide spectre of regeneration and repopulation strategies and, consequently, how they could be integrated to fulfil this purpose. When settlements stray from the common principles of urban economy and development, they require adapting evaluation perspectives. This is the case of ecovillages, a concept better described below, whose main – and overlooked – benefit has to be sought within social generativity.

2 Materials and Methods

2.1 Literature Review

A literature review has been performed on village regeneration and related indicators, drawing from more general works on indicators for regeneration interventions, through 4 query searches on the Scopus platform within "Article title, Abstract, Keywords." In particular, the 4 query searches reported the following output:

– Search 1 – "indicators" AND "regeneration" AND "village," 19 results (10 excluded);
– Search 2 – "indicators" AND "regeneration" AND "town," 27 results (9 excluded);
– Search 3 – "village regeneration," 15 results (0 excluded);

– Search 4 – “village” AND “repopulation,” 27 results (6 excluded);

Articles were excluded due to either being repeated in previous query searches or not matching the theme.

The distribution of the number of articles by year and country is reported in Figs. 1 and 2 below.

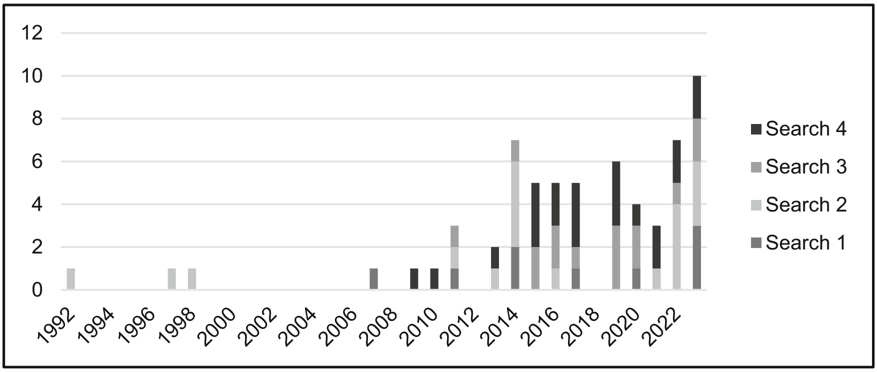

Fig. 1. Year-by-year distribution of publications about village regeneration and repopulation, focusing on the study of related indicators, divided into Searches 1–4 as reported above. Source: Elaboration on Scopus data.

The analysis of the related literature reveals that the theme has started to attract interest in the second decade of the 21st century. Despite the village depopulation phenomenon having long started, the acknowledgement of its problematic aspects has occurred much more recently, as well as the debate on its possible solutions. The number of publications on the subject has significantly increased in the last three years. Alongside the progressively higher consciousness of the theme, this growth can also be associated with the role of the pandemic. Indeed, this worldwide phenomenon has led to reflecting more on the potential of villages for more suitable lifestyles and their higher availability of biomass, producing a need to stop their progressive reduction. This is also shown by some changes of perspective, including the focus on co-working spaces for remote working [4], as they represent a feasible means to compensate for the lack of jobs in villages due to restriction measures.

In Italy, research has been conducted on heterogeneous aspects [5]. Some recent works [6] focus on the formation of indicators to distinguish between different typologies of villages in inland areas to support optimal decisions for regeneration interventions. Others explicitly address the issue of “repopulation” [7, 8], including criticism of stylistic restoration interventions that do not alter the social fabric of the hamlet.

2.2 Funding Initiatives for Village Repopulation

The two major initiatives to fund small town repopulation at the Italian national scale are the National Strategy for Inner Areas and the National Plan for Villages.

The NSIA was launched by the Agency for Territorial Cohesion in 2013. This Strategy, enacted for the period 2013–2021 and then confirmed for 2021–2027, aims to "promote and protect "Inner Areas" assets and local communities, enhancing their natural and cultural resources, creating new employment circuits and new opportunities." It identifies 72 "Inner Areas" throughout Italian regions, each with different geographic, territorial, and environmental characteristics, and promotes joint actions within them by allocating national economic resources for interventions in the supply of essential services, especially education, healthcare, and mobility.

The National Plan for Villages within the Italian NRRP includes two intervention lines: the first line, Line A, is aimed at funding regeneration strategies in 21 villages, each chosen by one of the Italian Regions and Autonomous Provinces within them; the second line, Line B, finances 229 villages selected through a national tender. Besides the selection modality, the two Lines also differ by the specific definitions through which they address the typology or villages to which funding is destined and the entity of the resources allocated to each village. For Line A, they refer to "villages risking abandonment or abandoned," and each is assigned 20,000,000 €; for Line B, they refer to "historical villages with a population below 5,000 inhabitants" and give them funding of 1,600,000 €. Thus, the purposes appear to be different. For the latter, the definition of "historical villages," alongside the limited entity of the allocated funding, suggests performing restoration interventions on buildings with historical value, implementing additional services, or supporting commercial activities to partially compensate for the laidback state of services and maintenance in small villages.

Indicators in the National Strategy for Inner Areas. In the NSIA, indicators are used to select the inner areas where to intervene. This is part of the initial desk phase, followed by a more detailed on-field phase. The indicators amount to 161 and are articulated into nine sections: Main characteristics, Demography, Agriculture and sectoral specialization, Digital divide, Cultural heritage and tourism, Health, Accessibility, School, and Cooperation among municipalities. As highlighted in a previous research work [9], despite their huge comprehensiveness, this approach has numerous criticalities related to the difficulty of collecting the data and driving quantitative comparisons. Moreover, one relevant aspect is its approach toward cultural heritage, which is mostly evaluated based on the tourist flows it can produce; thus, discourses around its identity-related and immaterial values are hardly encompassed.

Indicators in the National Plan for Villages. The fulfilment of the priorities in the NRRP is regulated by 14 common indicators identified by the delegated Regulation 2021/2106. They are used to evaluate proposals in each of the Measures and Tasks of the Plan, through a methodology that details their application modality. The ones used for the National Plan for Villages are "1 – Savings in annual primary energy consumption" and "9 – Number of enterprises supported". However, this priority structure entails some criticalities.

First, Indicator 1 evaluates the total amount of energy saving. For this reason, it evidently depends on the number of inhabited households and buildings on which energy efficiency interventions are performed. This produces a disadvantage for villages with an advanced depopulation process, as the number of inhabited buildings where to intervene is lower. Thus, villages with a population closer to the threshold of 5,000 inhabitants will be favoured by this indicator, compared to towns with lower population numbers. However, the abandonment risk is much higher for the latter than for the former.

On the one hand, Indicator 9 shares the same criticality as Indicator 1. Indeed, there is an evident correlation between the entity of the population of a village and the number of enterprises. Alternatively, other business structures aimed to maximise the value of this indicator would result in being uneconomical: this includes the establishment of multiple primary production-based businesses instead of a larger consortium or the launch of start-ups pursuing digitalisation yet less place-based, in clear opposition to the principles of the National Strategy for Inner Areas. On the other hand, due to the genericity of the NRRP's common indicators, Indicator 9 explicitly excludes one of the main driving forces in villages' regeneration processes, represented by non-profit enterprises, which are not counted in the total of supported enterprises.

3 The Case Study: Ecological Villages

3.1 Identification of the Settlement Typology

An alternative settlement practice, "ecological village" or "ecovillage," has been observed in several European countries. In the literature, it has been defined for the first time as a "human-scale full-featured settlement in which human activities are harmlessly integrated into the natural world in a way that is supportive of healthy human development and can be successfully continued into the indefinite future" [10] and later as an "intentional community whose members strive to live in a socially and environmentally sustainable manner, to practice voluntary simplicity, and to cultivate meaning, life satisfaction, and fulfilment" [11]. It is a settlement typology where inhabitants willingly initiate a lifestyle that deeply differs from urban and traditional ones. It is inspired by the search for spirituality and the prioritisation of profound values and human relationships by sharing goods and life and adopting mutual support as a foundational belief. Specifically, their principles have been codified by the Global Ecovillage Network's former president, Jonathan Dawson [12]:

- They are not government-sponsored projects but grassroots initiatives.
- Their residents value and practice community living.
- Their residents are not overly dependent on government, corporate, or other centralised sources for water, food, shelter, power, and other basic necessities. Rather, they attempt to provide these resources themselves.
- Their residents have a strong sense of shared values, often characterised in spiritual terms.
- They often serve as research and demonstration sites, offering educational experiences for others.

The pre-condition for the realisation of this community is the choice of an isolated place for the settlement: some examples include rural locations, with the acquisition of unused farmland by the community; however, in other yet fewer cases, these settlements are situated in depopulated villages and serve as the starting point for their regeneration and repopulation.

3.2 Ecovillages in Depopulated Villages

When taking place in an abandoned village, the initiation process of an ecovillage can be broken down into the following steps:

- an intentional community acquires or purchases an uninhabited location through self-funding;
- a stable community settles and restores uninhabitable households by performing self-funded or self-construction interventions;
- self-sufficiency is achieved through autonomous agricultural activities;
- the community starts to organise cultural, spiritual, and educational activities, which attract visitors from outside the village in the form of one-day tourism;
- small-scale hospitality activities are developed in restored buildings to host visitors for more than one day;
- the number of visitors tends to increase through communication activities.

In Italy, ecovillages in depopulated villages are mainly present in 3 Regions: Emilia-Romagna, Liguria, and Tuscany.

Among them, Torri Superiore has acquired significant popularity in Italian news [13]: it was one of the first examples of ecovillages in highly depopulated villages, supported by the local mayor. In 1993, a small community founded an association to restore and repopulate the medieval village and open a cultural centre to the public; nowadays, the ancient houses' physical conditions have been regenerated and the village attracts visitors on a regular basis.

Analysing the distribution of village regeneration initiatives in these three Regions reveals attractive percentages: there are six ecovillages out of 22 interventions in Emilia Romagna (27%), 3 out of 13 in Liguria (23%); finally, as many as 9 out of 25 in Tuscany (36%). Evidently, intentional communities in Italy are non-negligible stakeholders in village regeneration.

3.3 Suitable Indicators for Ecovillage-Based Regeneration

Conventionally, the choice of indicators to evaluate a context or phenomenon for fund allocation or simple monitoring is based on the individuation of transversal aspects to perform a homogenisation of different realities under common standards.

The outline above was aimed to highlight the peculiar and unique characteristics of ecovillages among settlements. Besides the general unsuitability of NRRP indicators due to the reasons detailed in the previous paragraphs, this narrative naturally leads to questioning whether this kind of transversality-based indicator structure is beneficial for evaluating anomalous situations. Instead, the conventional logic – rooted in urban development and performance – should adapt to these markedly different settlement principles. Consequently, valid indicators should arise from the comprehension of the peculiar advantages of ecovillages and the goal of compensating for their intrinsic and extrinsic weaknesses and needs.

This reflection led to the indicators proposed here, structured as follows:

- Benefit indicators evaluate the positive aspects of the object of evaluation;
- Risk indicators evaluate the degree of weaknesses and risks to which the object of evaluation is exposed.

This is not intended as a risk-benefit analysis: in that case, risks and benefits are compared to determine whether the latter overcomes the former and, thus, the convenience of a choice or scenario. In this case, the goal is different: the benefit indicators individuate desirable qualities which must be preserved and valorised – serving as a litmus test to identify contexts where the described pattern produces such virtuous environments – while the risk indicators can be used to assess the entity of their need for funding and could be useful for the public administration to calibrate tailored measures. Thus, the two are not meant to be interrelated or to suggest a trade-off evaluation.

Benefit indicators for ecovillages: social generativity. The peculiar aspect of ecovillages and intentional communities in depopulated towns has been individuated as social generativity. This concept has been first defined as "a distinctive social phenomenon apt to enlighten the relation between personal development and social change" [14]. This formulation suggests that different social paradigms affect individual evolution, which can directly affect significant social changes.

In relation to ecovillages, their unconventional social organisation and principles can produce this influence on their residents and visitors. Thus, three elements need to be analysed:

- The openness of the community to visitors required for the diffusion of such effects;
- The social satisfaction within the community, favouring value interchange;
- The degree of social generativity in the context.

The first can be straightforwardly evaluated through quantitative factors associated with hospitality: the average number of daily visitors and the total number of guests accommodated in local hospitality facilities.

The choice of the second group of benefit indicators is driven by the findings that the attachment within a social group is strongly affected by each individual's social satisfaction [15]. This serves as a precondition for ensuring that values are shared within the community and easily transmitted to visitors.

For the evaluation of social generativity itself, the survey items fine-tuned and tested by Morselli and Passini [16] can be used. In detail, they are the following:

- "I carry out activities to ensure a better world for future generations";
- "I have a personal responsibility to improve the area in which I live";
- "I give up part of my daily comforts to foster the development of next generations";
- "I think that I am responsible for ensuring a state of well-being for future generations";
- "I commit myself to do things that will survive even after I die";
- "I help people to improve themselves".

These items (later indicated as (2)) have been chosen as they mainly focus on the aspects of social responsibility within the broader concept of social generativity, considered its most advantageous dimension in terms of effects on the outer environment (urban contexts).

Risk indicators for ecovillages: territorial vulnerability. The most evident risks for ecovillages in hamlets are related to natural and environmental hazards. Places where minor centres are usually located – especially mountain areas – are intrinsically more exposed to disasters [17]. This is compounded by the scarcity of infrastructural dotation in ecovillages: most villages that were abandoned decades ago suffered from this issue, which was never solved due to the absence of national actions at that time; then, the self-funding processes in ecovillages could not compensate for this laidback scenario autonomously.

For these reasons, the proposed risk indicators focus on natural/environmental and physical risks. Useful indicators have been codified in an interesting work by Lauria and La Face [18]. In particular, concerning natural risks, the following ones are here adopted:

– History of the village's exposition to destructive events (1–5 standardised scale);
– Expected damage from natural events (1–5 standardised scale).

Concerning physical exposition, the following ones:

– Site accessibility (Driving time from the closest centre with >5,000 inhabitants);
– Quality of the transport system (1–5 standardised scale);
– Presence of water and electric networks (0–1).

The goal of these risk indicators is twofold: on the one hand, as mentioned above, to identify suitable economic provisions to include in a support measure; on the other hand, to produce an ad-hoc map of vulnerabilities to highlight the specific suitability of abandoned villages for resettlement initiatives. A synthesis of the two groups of indicators is shown in Table 1. The code "Rev" in the scale is attributed to the items whose judgment provides an opposite impact on evaluating the indicator.

Table 1. Synthetic table of the proposed benefit and risk indicators, reporting typology, evaluation modality, and items.

Group	Indicator	Item	Scale
Benefit	Community openness	Number of daily visitors	Number
Benefit	Community openness	Number of available visitor beds	Number
Benefit	Social satisfaction	5 survey items (1)	%
Benefit	Social generativity	5 survey items (2)	1–7
Risk	Natural exposition	History of disasters in the village	1–5 (Std)
Risk	Natural exposition	Expected damage	1–5 (Std)
Risk	Physical exposition	Site accessibility	Time
Risk	Physical exposition	Quality of transport systems	1–5 (Std, Rev)
Risk	Physical exposition	Presence of water networks	0–1 (Rev)
Risk	Physical exposition	Presence of electric networks	0–1 (Rev)

4 Conclusions and Future Developments

Post-humanism has brought about a rethinking of the concepts of progress and place. Progress has been deconstructed as an urban-rooted idea whose need for upgrading means, tools, and habits is hinged on a speculative process requiring a constant production of the 'new' to support modern economic paradigms. The sense of place is gradually changing meaning, with virtuality affecting sensoriality and bringing to a more conceptual and utilitarian fruition of space.

Villages are often regarded as a mere diverse territorial resource, highlighting that they could be exploited more, as they could be engaged in dynamics similar to city centres: opportunities for smart working and business development, tourist flows, or historic core preservation. The main point of this article refers to their potential key role in responding to these global issues, offering the opportunity to experiment with different ways of life that are no longer possible in broader and complex urban contexts. In this scenario, individuals act as pivots to reflect such small-scale social changes in macroscopic paradigm transformation within modern society. Valuing this process is the first step to examining ad-hoc measures and tools to identify and support these contexts.

Due to the interdisciplinarity of this analysis's background, further steps need to be conducted in the fields of social studies, ecology, and territorial analysis to evaluate the variability of values and results throughout the available examples of this settlement typology, fine-tune indicators and items better, and, if necessary, integrate them with others.

Thus, the proposal of indicators fine-tuned for the peculiar context of ecovillages is not driven by the need to suggest a priority for funding measures' decision-makers. Instead, the purpose is to show that establishing allegedly transversal and neutral indicators implicitly sets a priority. That is, favour the development of urban-styled activities in villages without acknowledging the impact of these transformations on the territory and neglecting alternative possibilities. Instead, this indicator structuring process is rooted in identifying the peculiarities of a settlement typology and their inclusion in the values promoted by an economic support measure. Future perspectives include testing the indicators developed on an adequate number of the eco-villages mentioned, as well as evaluating the difference with benefit scores that can be achieved in standard urban contexts to better prove the peculiarity of these settlements.

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Decision-Making in Complex Infrastructure Work: Data-Driven Intuition?

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Abstract. Decision-making processes for developing and maintaining urban infrastructures are characterized by high degrees of complexity and uncertainty. Increasingly, digitized technologies and data analytics are adopted to support (or replace) such decision-making processes. Yet, urban infrastructures are inherently complicated because their development and maintenance are fraught with divergent stakeholder values and multiple object positions, entailing multi-faceted considerations, risks, and power relationships. In such contexts, judgement, morality, intuition and engaging in here-and-now materiality are often needed in order to bring together heterogeneous worlds. The inherent tension between multiplicity and uncertainty in working with infrastructures and the evidence-based reasoning of automated expert systems requires scholarly attention to issues such as the extent to which intelligent technologies should be authorized to make decisions independently and what can be lost when control is relinquished to the algorithm. We present an ethnographic study on pipeline maintenance and repair work in an urban environment to understand (1) the specificity of infrastructure maintenance practices and (2) how practices of deciding are changing with the increased digitalization of pipeline monitoring. The study follows district heating maintenance workers in Denmark on their transition from intuition-based to data-driven planning and decision-making, as their work is increasingly supported by drone-operated thermographic cameras, active monitoring and data visualizations that render leaks from underground pipes 'visible'. We reflect how digitally mediated decisions differ from previous reliance on vigilant citizens and workers' first-hand experience. Empirically, the study investigates practices of deciding – a state of relational entanglement that necessarily creates encounters among multiple worlds. Conceptually, it begins to explore the consequences of algorithmic computing and multiple computational ontologies for how decision-making emerges in the context of complex (infrastructural) work. In such an account lies the opportunity to further specify what it means to *be deciding* or *enacting a decision* in an era of extensive digitalization.

Keywords: Decision-making · enactivism · infrastructure · district heating · innovation

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1 Introduction

Decision-making has traditionally been equated with judgement, intuition, creativity (see, e.g., [1]), and perhaps with meaningful pursuits for workers and organizations trading with knowledge and expertise. None of these characteristics can be attributed to technologies or "intelligent" algorithms. Originally, this "specialty" was thought to be a leap in the decision tree that allows humans to skip decision-making steps [2]. By following heuristics or rules-of-thumb, humans are able to efficiently make decisions even when information is scarce and time is limited [3]. The first expert systems of the late 80's and early 90's intended to support human decision-making were based on such heuristic techniques, otherwise known as soft computing methodologies [4, 5]. However, due to limited results, this approach was left aside if not abandoned for one that relies instead on "brute force" mechanisms where data volume and processing power become central. In fact, modern computers are able to process data in quantities and at speeds that are alien to humans, thus streamlining decision-making processes in deterministic and relatively stable environments. Yet, with the latest advancements in machine learning algorithms, combined with big data availability and ever-increasing processing power, (partly) automating decision-making is becoming a reality also in more dynamic and stochastic environments – such as complex infrastructure systems – despite the limited use of human-like heuristics.

In the context of urban infrastructure development and maintenance, innovations are also shifting in the direction of automation by the inclusion of modern expert systems, big data analytics, and artificial intelligence [see, e.g., 6, 7] for activities ranging from forecasting and planning to monitoring and maintenance of networks and critical service infrastructures. For example, in the energy sector, intelligent expert systems have been introduced for forecasting energy demand [8, 9] and energy price [10]. Additionally, efficiency-centered ontologies [11] have been utilized for encouraging the reduction of energy usage. In the renewable energy sector, big data and expert systems have also been deployed to forecast supply [12] and for inspecting and monitoring the structural integrity of physical infrastructural assets [13]. While such innovations are currently dispersed, contextual, and locally deployed, the promise of pervasive digitalization is to enable a 'system of systems' approach to decision-making in increasingly complex infrastructure systems [14].

As things stand today, such tech-engineered decisions involve processing large volumes of hard data by means of evidence-based reasoning. Yet, infrastructural decision-making processes require tolerance for imprecision and necessitate an experiential dimension for justifying partial solutions and/or the selection of opposing courses of action based on subjectively established criteria. This implies that the role of human expertise is still very much relevant, but it is its qualification in the decision-making process that requires attention. On the one hand, understanding what is "lost in automation" becomes essential to exercise judgment that makes contextual and situational sense. On the other hand, decision-makers now engage with multiple expert systems simultaneously. Unlike traditional decision-making support tools—i.e., single data-processing technologies thought of as tools or stand-alone artifacts—individuals now interact with multiple computational ontologies at once, as they must navigate heterogeneous technologies with varying capabilities, input requirements and operational standards [15].

This paper is concerned with these two key points in the study of contemporary – i.e. digitally mediated – decision-making, understood as a divergence from traditional approaches. To be able to consider these points more effectively, this paper takes an enactivist perspective on human cognition and decision-making, and applies this framework to the Case Study of a large utility company. The paper concludes with an outline of the modifications and integrations that are necessary to the study of human decision-making in digitally mediated and complex environments.

2 Background – Enactivist Tradition in Cognitive Science

From a historical perspective, the study of decision-making has always been intertwined with traditional views in the philosophy of the mind and cognitive science [2]. This is inevitable if the research objective is to understand decision-making as a process or as a combination of mechanisms. This isolationalist perspective has been challenged more and more frequently in recent years (e.g., [16, 17]). Under the new lens, cognition (and decision-making) is considered as inseparable from action.

As stressed by enactivists, cognitive processes should not be conceived of in terms of basic 'Sense (input) → Plan (compute) → Action (output)' models that reduce 'cognition' to the consumption of mental content [18]. According to such cognitive models, decisions and decision-making are separate from the very actions that are decided upon. Not only does such an account treat decision-making as disembodied—i.e. happening in the isolated brain, but it also builds on a high degree of intellectualism by assuming that humans, much like computer programs, act on the basis of clear deliberations and reasons—one example is the decision tree mentioned at the beginning of this article. Put in simple terms, this view presupposes that decisions entail that one is 'making up one's mind' prior to acting. This is assumed to happen on the basis of mind-internal reasoning processes, which involve gathering information, organizing it on the basis of pre-defined criteria, and weighting the alternatives, all leading to a decision (see, [19]). Furthermore, while such content-based views might have some merit in the context of higher-level non-routine tasks (e.g., long range planning, bomb defusals; [20]), the views are inapt for coming to terms with more "mundane" decisions that happen "on the fly", that is, without much deliberation and overt reflection (see, [21]).

Under the lens of traditional cognition described above, users of decision-support systems are depicted as atomic individuals relying on the computational power of technologies to enhance their cognitive abilities and perform tasks more efficiently. Yet, such a view completely disregards the intricate socio-technical reality of digitally mediated experiences, and attenuates the importance of material relations, social interactions and contextual factors that mobilize action – and hence, decisions. In this regard, one of the key insights of the enactivist tradition in cognitive science is that decision-making is fundamentally *embodied*, meaning that it is inseparable from action, and should thus be studied as such.[1] However, another very important aspect of this perspective—at least in relation to the key points raised in this article—is the way in which the divide

[1] An interesting line of enquiry would be to ask on the role of *embodiment* in the case of fully automated decision making. There are two considerations here. One is that the concept has been developed to study human cognition and, as such, it may be difficult to adapt to machine-based

between external and internal cognitive resources dissipates. In fact, if decision-making is embedded and enacted in a practice, then there is a clear dependence on different resources that cut across the inner-outer dichotomy, and involve phenomena irreducible to a strictly psychic or mental ontology. In this sense, it is the interplay of cognitive resources involved in making the decision that creates the conditions for interpreting and performing it. For example, it is the process of writing an email that shapes the way in which it is ultimately written. This depends on anticipation, experience, existing history with the recipient (if any), the software used, the hardware involved, and the actual action of typing words. This dynamic interplay (i.e. performance) between resources opens up interpretation (sense-making) avenues [21].

In regard to the nature of tech-engineered decision-making, there are two points to be taken from the enactivist approach to cognition. One is that the "heuristics approach" is probably falling short of defining the human "specialty" in that it assumes a rigid structure, or an Olympic paradigm of reference for decision-making [21]. An enactivist approach is, instead, much more fluid in that it defines the structure for decision in a dynamic and intertwined way such that action *is* decision. From this angle and using classic terminology, heuristics lose their stable anchor but re-set it depending on the dynamic interplay between all socio-technical cognitive resources involved. In this connection, it is even doubtful that a hypothesis or idea is developed. This is not limited to the decision-making support tool and the decision-maker, but it includes collaborators, experience from past and current technologies, and social norms of interaction and especially of use/practice (or a cognitive "meso" domain; [22]). Perhaps using the word "heuristics" is incorrect here since its interpretation changes quite dramatically in this theoretical frame. Nevertheless, under an enactivist lens one can still state that anchor-dynamic heuristics (or meso-anchored; see [22]) are missing from current computational expert systems and other technological solutions.

The other point that emerges from the enactivist approach builds on the previous paragraph. If decisions are action-bound then the repetition of these actions performed on several different tools and systems has to have constraining and enabling effects on the decision-maker. When using a tool—e.g., an expert system—the user develops specific ways of interacting with it, depending on previous knowledge, expertise, knowledge of similar tools, etc. No matter how the user develops these habitual usages, the point here is that they develop them. Some of these uses establish themselves as recurrent, driven by the success of repetition. This is a feature of *extended* cognition [23] that is enhanced by repetition [24]. However, through repeated action, decision-making becomes *mechanical*, in the sense that it avoids actual and explicit choice among alternatives [21]. This relatively mindless activity offers potential issues when the user switches tools or needs to use multiple, heterogeneous tools a once. The interesting aspect here is to understand how different ontologies can be preserved by avoiding the practice-bound biases mentioned above. In other words, exploring the elements that allow for a decision to

(or artificial) processes. The other is that the automated decision making becomes part of a wider cognitive process and, as such, part of the action chain related to it. Hence, embodiment works in relation to cognition, seen from a wider perspective (i.e. including all cognitive resources, material, immaterial, human, artificial, etc.).

become *choice-based* again once formed as a *mechanical* decision becomes particularly important.

3 Introducing the Case

The case study follows a Danish utility company that services a range of critical infrastructures, including water supply, gas and district heating networks and serves ca. 2.7 million customers. A significant part of the company's operations relates to the maintenance of approximately 2800 km of district heating pipelines, including leakage detection and repairs. Traditionally, leakages in the pipeline network are detected by either workers on scheduled maintenance duty or by vigilant citizens who report the sight of green water (water chemically altered to be distinguishable when leaking) above ground or in building basements. Yet, these methods are insufficient to provide an overview of all leakages in the network and only allow for a reactive approach to leakage detection and repair. In recent years however, maintenance work started to slowly shift towards a proactive approach with the introduction of a range of specialized technologies including drone-operated thermographic cameras, interactive orthomaps based on thermal surveillance data (Teraplan), active monitoring, and data visualizations tools that render leaks from underground pipes 'visible' before the green water surfaces (i.e., before leakages become critical). However, none of these technologies can, by themselves, detect and visualize leakages throughout the entire pipeline network. This is because the district heating network is a complex and interwoven system of heterogeneous materials, outdated and innovative engineering solution and legacy technologies:

> "We have one of the oldest nets in the whole world, but our net is very different. We have areas that are only a few years old and we have ones that are close to 100 years old now, or more actually." (Team Leader, MD)

Because the pipeline network has such a heterogeneous material configuration, each network section requires different kinds of technologies for rendering leakages visible. For example, the active monitoring system requires that straight, pre-insulated iron pipes are fitted with an alarm system consisting of electrical wires that can signal in real-time the presence of water in the insulation. However, this technology is extremely costly and hard to implement in all types of piping, and therefore only (newer) parts the network are covered by active monitoring. Because large parts of the network are not covered by active monitoring, the drone-thermography platform was introduced in the department's operations for detecting leakages in pipes that are either very old, too small to fit the alarm system or that requires malleable materials for fitting at bents and cross-sections in the network. The drone-based system has been dubbed "the best possible way, without doing it the right way" by the district heating workers because in an ideal world, the whole network should be covered by active monitoring:

> "We can detect [a leakage] fast if we have automatic alarm surveillance, then we can actually catch it the same day. This is the best solution we have. But we don't have this in all our piping because some people didn't want to invest in this from the beginning. And I think this will be the future, we're just not mature enough

> for it yet. And this is where the drones come in. And for most [drone-detected] leakages we end up fixing the pipes the best possible way without doing it the right way because the technology is old and we are bound to making a one-to-one exchange." (Team Leader, MD)

However, taken together, these leakage detection and data visualization tools make it possible for district heating workers to have a more proactive approach to network maintenance, as the department now relies on an abundance of data on thousands of potential and actual leakages to plan repairs and take preventive actions in their maintenance operations. As the team leader at the MD observes, this often means doing things the best possible way without doing them the right way. Increasingly however, these expert systems become epistemic objects in their own right, emerging at the crossroads between the past materiality of the infrastructure and the future ideals of district heating workers, and enabling new ways of thinking about and acting on leakages. Among other, changes are emerging in the way repair works are planned and interdependencies between leakage cases are handled:

> "So back to something that I said earlier that we do not plan ahead a whole lot. But [employee responsible for drone cases] is actually the only one planning ahead a whole lot, because he knows he has to share the diggers, and he has to share the welders with us, so he has to plan, and mark areas where he maybe takes two As and a B [leakages identified by drones are ranked based on severity of water loss, where A is the most severe] and say: 'These three are in close proximity to each other, please go and dig all three up [...]." (Operations and Maintenance Engineer, MD).

As the new leakage detection and repair practices evolve through mutual interference with existing domains of the maintenance work, the complexity of socio-technical relations is also increasing, as district workers now require new technical skills and expertise to detect leakages and make prioritization and resource allocation decisions. Furthermore, the way in which leakage notification from traditional sources (i.e. citizen notifications and scheduled maintenance) are handled is also increasing in socio-technical complexity as thermographic and active monitoring data are being increasingly used together with traditional sources to e.g., triangulate leakage data, enhance the precision of digging areas or cluster cases to optimize the use of contractor time and other scarce resources.

The case of the district heating workers on their digital transition attests to how the introduction of new systems for leakage detection and visualization, which in principle should make the work easier, cannot eliminate work complexity, nor render decision-making fully habitual or mindless. Instead, they give rise to task-complexity in a different way. The efficient use of the expert systems not only requires the acquiring of new habits, skills and expertise (e.g., operating the new software, acquiring specialized knowledge, adjusting to different perceptual environments) but also a different approach to the nature of the leakage, and thus different kinds of expert knowledge and ways of working. Yet, it also entails a task-performance filled with complexity and uncertainty simply because the nature of the task is complex and highly unpredictable.

4 Discussion and Concluding Remarks

Traditional decision-support tools have thus far proven faithful partners for accomplishing work that is both complex and ambiguous, as they have automated many repetitive and routine tasks, creating space for non-routine work, and supporting decision making [25]. At the same time, this paper argues, there is (a) the need to understand what is lost from massive implementation of these technologies, and (b) the repercussions of using multiple tools at once. Of course, there is the possibility that these two points are irrelevant—i.e. that nothing relevant or very little is lost and that there are no issues related to multiple tools usage. By adopting an enactivist approach, this paper demonstrates that these two points are, indeed, relevant by showing that decision-making is necessarily action-bound in the sense that there is no decision made in isolation—i.e., happening or explainable by considering the various elements separately.

First, there are *procedural* implications to decision-making (better in-the-making). The Case Study is an example of how the implementation of modern technology (unmanned thermo-scanning machines or drones) has been introduced in the decision-making processes of a department in a large organization. This was not a simple addition to existing procedures. Quite the opposite, it forced workers to think about their operations differently, to engage with the data and with each other, to find ways to operate under the new conditions. Most importantly, this prospect was not planned in the sense that none of the actors could anticipate what and how much change the new technology would have brought to their operations. The decisions came as actors were acting upon the information. Hence, decisions on how to establish operational procedures came about as they "fiddled" with the technology.

Second, there are implications to *substantial* decision-making practices. Once changes related to a meta-(meso-)domain of general procedures in the department were in the making, there also came decisions on the "usual" (standard) tasks to accomplish (i.e. leakages management). The actors were confronted with such rich and abundant data that it required a different approach to the tasks. By working with the different software solutions, they realized that, for example, tasks (leakages) could be clustered. This required an effort in abductive reasoning, at times, to understand the explanatory hypothesis as of why these tasks could/should be clustered. The following decision is typically that of acting upon the tasks. Once again, it is the action that allows the actors to make decisions on the tasks, which to prioritize, and how to do so.

Last, we show that the kind of decisions involved in the context of complex human socio-material systems can be said to be of a hybrid kind. Hybridity here entails that the decisions involve deliberation (or, at least, unmechanical exploration) in relation to a particular purpose combined with more mechanical or habitual use of a tool, artefact or computer at hand (see, [26]). The threshold for determining whether this is the case is to consider a given task and whether the task can be accomplished solely in a habitual manner or if it is bound to involving a distinctive kind of novelty - or uniqueness - that affords an ever-more tailored or task-sensitive approach. In such a connection, the decision-making happens in the context of tool-use where the enabling technology or tool comprises an epistemic thing in the specific sense of allowing for the uncovering of novel so-called knowledge objects (see also [27]).

In summary, this paper is an attempt to open up the discussion on tech-engineered decision-making, intended as practices. By applying an enactivist framework to decision making in a Case Study, we have outlined two fundamental aspects of how human cognition shapes our understanding and use of these tools. We claim that there is a *procedural* implication, on the general approach to the technological tool, and a *substantial* implication, on the way in which decisions are actually practiced.

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Discretion, Justification, and Legitimation in Contemporary Urban Decision Making. A Reflection on the Role (and Risks) of Urban AI

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Abstract. In the face of urban artificial intelligence, what is expected for urban planning is the emergence of automation as an unprecedented paradigm. While there is no lack of conflicting opinions on the dissemination of AI, the paper proposes a reflection on the impact of this technology on three distinctive features of urban decision-making: discretion, justification, and legitimation. Drawing on Luigi Mazza's theoretical endeavors, the research argues that urban decision-making cannot be reduced to the logic of automation. Mainly because of the inherent discretionary character of choices within the planning arenas, the decision-making process is deeply conditioned by discursive strategies. Given such premises, AI deserves to be carefully framed. To do this, the paper inquiries into artificial intelligence's genealogy, so to outline a consistent definition as emerging from relevant literature. Yet, to grasp AI's overreaching epistemological, technical-operational, and ethical-political implications, it is convenient to frame it within the wider debate on the rise of a new science of the city (of which AI constitutes one of the undisputable pillars). Following the assessment of discretion in planning decision-making, the paper indulges on the current disciplinary discourse around AI, shedding light on the possible risks inherent to the paradigm of automation.

Keywords: Artificial intelligence · Urban decision making · New urban science

1 Artificial Intelligence and the Discursive Nature of Planning and Urban Decision Making. An Introduction

The article proposes a critical reflection on three distinctive elements of urban decision-making – discretion, justification, and legitimation – in the face of the emerging paradigm of Urban AI. These three concepts, drawn from a critical reading of Luigi Mazza's theoretical reflection on the discursive nature of urban planning, are today worth considering in the face of AI's disruptive rising. Being the latter not only a mere technological innovation – however powerful and impactful may it be – but rather a new cognitive paradigm. If, as acutely argued by Luciano Floridi [1], artificial intelligence is a new form of the ability to act, then concepts such as discretion, justification and legitimation are called into question by the new cognitive paradigm of 'automation'.

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In the field of urban planning and decision making, this paradigm shift has been well described by Federico Cugurullo [2], according to whom «Arguably for the first time in history, artificially intelligent urban technologies are taking the management of urban services out of the hands of humans, operating the city in an autonomous way» (p. 2). If this is true, what we are witnessing is a radical change; technology is no longer limited to facilitating the management of digital infrastructures (as promised by the smart city paradigm), but directly rules «the domains of urban governance and planning» (p. 2).

Of course, this involves a critical reflection on the role of experts. If the decision entrusted to AI is, as Cugurullo claims, specifically 'automated', what about discretion? How does the role of expert change, if a decision is no longer sustained by arguments but by data? Can the entire planning process really be reduced to a mere analysis and interpretation of data, entrusted to predictive algorithms? The hypothesis I will argue here is that, despite the pervasiveness of the disciplinary rhetoric linked to smart urbanism [3], urban decision-making cannot be reduced to the logic of automation.

To properly argue such hypothesis, the contribution dwells on the lesson of Luigi Mazza (1936–2023). As a planning theorist and internationally renowned scholar, Mazza devoted a considerable part of his work to deepening the scope of discretion in urban planning and decision-making. Putting discretion in relation to two relevant dimensions such as justification (of policies) and legitimation (of the expert), Mazza stresses the essentially discursive nature of the planning process. This approach, which finds numerous convergences with the Argumentative Turn [4], recognizes that planning gains legitimation from technical knowledge – which provides the 'objectivity' planning needs [5] (p. 38). However, since technical decisions are 'validations' of political choices (taken on a territorial scale), what follows is that the task of the planner is not *to explain* a policy, but *to justify* it [5]. This justification can only be a process of argumentation, where each justification is by its very nature *partial* and not *global*. Since policies are necessarily selective (and subjected to an unavoidable share of uncertainty as well), Mazza explains, the justification can only reflect the legitimate *political* discretion behind the plan. Overall, Mazza outlines a conceptual framework of rare rigor: planning is a technical knowledge called *to justify* political choices which, as such, are *discretionary* inasmuch they are subjected to arguing and bargaining [32].

What is worth considering today is precisely the questioning of these foundational elements of the decision-making process. The specialized planning literature, often drawing from case studies and in-depth empirical research, seems currently interested in demystifying fears and prejudices arising around the use of AI [6] and, more recently, to chart conceptual sources and spatial implications of the so-called AI urbanism [7]. In this paper, instead, I dig deep into a theoretical reflection concerning the implications of AI in contemporary urban decision-making. On the methodological ground, I draw on planning literature to concisely assess the disciplinary discourse revolving around the rise of Urban Artificial Intelligence (paragraph 2). The purpose of such literature exploration is to extrapolate a cogent definition and specific characters of UAI in contemporary urban planning. Yet, an in-depth understanding of UAI requires further framing within a much wider academic, professional, and cultural movement concerning the return to scientistic postures within Planning theories, with significant impact on planning practices and specifically on decision-making (paragraph 3). It is the 'new urban science' [7–12]: a multidisciplinary research field animated by a variety of experts, ranging from urban geography to computer engineering, and promoted by a solid epistemic community, in the meaning proposed by Kitchin *et al.* [13].

Both paragraph 2 and 3 are aimed to depict, in large brushstrokes, the impact of scientization of the disciplinary discourse around AI and the 'science of the city'. Such framing, as lengthy and preliminary it may appear, is nevertheless crucial so to critically contextualize my account of Mazza's reflection about discretion, justification and legitimation in urban decision making (paragraph 4).

Hereafter such in-depth exploration, the paper focuses on the following research question: given that discretion (in planning) implies a technical, political, and ethical responsibility on behalf of the planners; in the absence of such discretion, what about the argumentative dimension of the urban decision making? Thus, focusing on the critique to the dominant trend of *datafication* [14] – which configures a model where data collection effectively precludes the possibility of arguing decisions (which have already been made, algorithmically) – the paper calls for a greater balance between quantitative and qualitative methods in urban planning.

Finally, in its conclusions (paragraph 5), the paper challenges the current state of the disciplinary debate on the use (and potential) of AI technology, exposing the risk of a scientistic drift (already experienced in the past) whose implications would be detrimental to the disciplinary field.

2 Planning (in) the Autonomous City: A Definition of Urban AI

One cannot understand the magnitude of the artificial intelligence revolution, let alone its impact on urban governance, without first trying to define it properly. So, what is artificial intelligence and in what terms is planning literature interested in it?

Firstly, according to Cugurullo [2] it is convenient to pause on the two key sub-concepts that make up the definition of AI. The first one is 'artificial', which designates everything that «does not arise from a natural process» (p. 3). The product of such an artificial process is an artifact. An AI, Cugurullo argues, usually resides in artifacts (e.g., a car).

The second one, 'intelligence', is – as the author himself observes – more difficult to unpack. If the purpose is to understand how intelligence manifests itself in AI [2], then it is not necessary to dwell on a general definition (arduous task). It appears more profitable, instead, to indicate the abilities that intelligent entities should possess to be defined as such. The first has to do with learning, «intended as gaining knowledge, both directly by sensing the environment through, for instance, cameras and microphones, and indirectly by means of large data sets installed by the developers» [2]. The second skill consists «in the capacity to make sense of the acquired data by extracting concepts from it» [2]. The third is the ability to manage uncertainty while the fourth signals the ability of using «the collected and potentially incomplete information to make decisions and then act in a rational way» [2]. The fifth and final ability lies in the exercise of «the above skills and capabilities in an autonomous way or [...] in an unsupervised manner, meaning that humans are out of the loop and do not control or steer the AI's decisions and actions» [2]. Hence, according to Cugurullo, the combination of these two sub-concepts provides a proper understanding of an AI «as an artifact able to acquire information on the surrounding environment and make sense of it, in order to act rationally and autonomously even in uncertain situations» [2]. This is an effective definition that fits well with the three categories of AI described by the author (respectively: autonomous cars, robots, and city brains).

What has not been emphasized enough so far is that, to function, artificial intelligence needs data. As appropriately argued by Thomas Sanchez [15], «An AI program takes inputs of a large quantity of data, analyzes it according to a set of rules, and produces outputs, which can take a variety of forms depending on the types of inputs and types of questions being addressed» (p. 2). Even the ability to learn, already reported by Cugurullo, necessarily depends on the possibility of acquiring data through which to «mimic or improve upon human intelligence» [15] (p. 1). Besides, if it true that «What makes AI "intelligent" is its ability to use results from the analysis and outputs to update or improve the overall process» [15] (p. 2), this procedure is not so far from the one adopted in daily planning practice, in which planners are called to gather information, to make sense of it and to provide viable solutions to planning and policy issues [15].

This sounds correct also because the interest of the discipline for the AI goes back to some decades ago [16]. In general, as Cugurullo [2] observes, the field of artificial intelligence is not a novelty – both as a technology and in terms of applications in the built environment[1]. A more detailed account is provided by Sanchez *et al.* [17], where it is stressed that the potential of AI for planning goes back to the late 1950s and early 1960s. Although at the time possible advancement were frustrated by the limited availability of data, later «the implementation of data collection sensors that track movement patterns, land-use changes, real estate transactions, energy usage, etc.» (p. 3) have been remedying such shortcomings.

The fact that the field of artificial intelligence has attracted the interest of urban planning for so long deserves, perhaps, further reflection. The most convincing hypothesis, illustrated below, is that the interest in AI falls fully within the scientific paradigm of planning. As extensively illustrated in the literature [18–22], the idea that planning should be conceived and practiced in the same way as a scientific enterprise has been quite successful – not only in Planning Theory but also in professional practice. Today, the scientistic posture is back in vogue, spread by the smart city paradigm and, even more recently, embodied by the rise of the 'new urban science'.

3 The Rise of the 'New Urban Science'. Framing AI Within the Return of Scientism in Planning

Artificial intelligence opens-up a horizon in which technological progress will shape the future of urban realms and human civilization. Indeed, as Palmini and Cugurullo [7] point out, that between technological innovation, scientific enquiry and urbanization is an ancient relationship. The roots of this interrelation can be traced back to the birth of

[1] «AI as an idea, as a field of research and as a technology is not new, nor is its application in cities. The field of artificial intelligence begun to be cultivated in the middle of the twentieth century and, since then, many applications of AI (albeit in an embryonic form compared to what we see today) have touched the built environment» [2] (p. 5).

the scientific method, in the modern age, by Francis Bacon (1561–1626)[2]. According to the authors, it was in the 19th Century that the «Baconian seed» germinated in urban planning – fueling that search for objectivity and scientific rationality that will bear fruit in the following century, when the discipline was institutionalized definitively [23].

Precisely because behind the relationship between technology and urban development there is such a rich and complex history, it is worth framing the emergence of artificial intelligence within a wider disciplinary upheaval. Today, unlike in the past, the scientization of urban planning is less depending on the emulation of epistemological paradigms imported from the hard sciences – as it was for urban modeling in the 1970s [24]. Rather, the science of the city outlines a new field of research and practice: a new science that, by virtue of an alleged multidisciplinary vocation [25, 26], aspires to 'know the city' and to guide its future evolution. As stated by Karvonen [27], the 'New Urban Science' takes advantage of digitalization to increase knowledge about the city. The author – drawing on the vast literature that has arisen in recent years around the theme (and which has grown significantly in the aftermath of the pandemic) – takes an unprejudiced approach and effectively reconstructs the state of the art and the future potential of urban science. Here, the main interest lies in two distinct aspects. The first concerns the genesis of urban science, to be found in the centuries-old interweaving between urban development, scientific enquiry, and technological innovation (as noted above, about artificial intelligence). So, while it is true that the roots of this 'new science of the city' are ingrained in the history of planning, it is equally true that its potential has long remained unexpressed. At least until modern advances in computational power, which allowed urban scientists «to model urban functions and predict patterns of growth and change» [12] (p. 3). A further enhancement occurred in the late 1990s, the authors explain, when «the World Wide Web […] introduced new networking capabilities for urban science and spurred a wave of new programmes, initiatives, research centres, and laboratories to develop and apply quantitative computational approaches to analyse urban dynamics» [12]. Finally, the current focus on *smartness* – coupled with the pervasiveness of urban digitalization – «has further invigorated urban science practices through the introduction of Big Data, ubiquitous sensor networks, datahubs, control centres, and other digitally networked artefacts and systems» [12] (p. 3).

All in all, beyond the rhetorical strategy employed by its staunch promoters, such 'new urban science' is, quite simply, the result of unprecedented technological and scientific progress. Therefore, the positivist attitude underlying the development of this strand of research (in theory as well as in professional practices) is nourished by the utilitarian rationality of techno-science [28]. Artificial intelligence is positioned at the frontier of contemporary techno-science and, as such, is also a challenge for urban planning and policymaking. However, and this concerns the second important aspect, urban scientists seem to underestimate the epistemological challenge and, above all, the impact

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[2] «[I]n his urban and social utopia called the New Atlantis, Bacon portrays science and technology as the engine driving the improvement of society. Here technology is no longer just an important factor in the urbanization process: it becomes society's governing principle and the dominant force capable of promoting human development. In his philosophy, Bacon replaces Plato's philosopher kings with a class of scientists capable of governing the urban realm and keeping it healthy, in virtue of their technical and scientific expertise» [7] (p. 3).

on decision-making that the rise of urban science brings with it. If the desired objective is that of an increasing automation of the decision-making process (guaranteed by the multiple applications of AI), it is legitimate to question to what extent this undermines discretion, justification, and legitimation. In the next section I dwell on the assessment of such impact by drawing on the theoretical-conceptual perspective of Luigi Mazza.

4 Discretion, Justification, and Legitimation in the Face of Automation. An Enquiry Through the Lenses of Luigi Mazza's Theoretical Work

Although the techno-scientific knowledge – and the relative technical rationality that feeds it –, by virtue of the long-standing alliance between technology and urban development, is increasingly enhanced in planning, the wisdom available to planners is still modest and rather circumscribed. This appears in clear contradiction with the well-known hyper-rationalist aspirations of modern planning[3] and with the more recent aspirations of the 'new urban science'. Synthesizing a little, one could say that in the planning process technical rationality is not self-sufficient. This depends on whether we understand rationality as a special form of decision-making [30]. If so, then it is inevitable to recognize that the urban decision-making process *as such* is characterized by a sphere of discretion that cannot be overridden in any way – unless you want to deny the political nature of planning[4].

In more detail, because of this discretion and because «the policies of the plan are [necessarily] selective and not comprehensive» [5] (p. 39), the task of planners is not so much *to explain*, but *to justify* a policy (p. 38). Here, therefore, to the first of the three characteristics introduced in the title (discretion) is added the second one, justification. What is the significance of 'justification' and in what terms does it differ from 'explanation' within urban decision-making? Mazza argues that «justification is [...] taken as a discourse of an argumentative nature, and the reasons, brought to show that something is right, must be consistent with the argumentative nature of the discourse [...]. In other words, the reasons lack the demonstrative cogency that can sometimes be demanded by

[3] Mazza cleverly argues that «the search for a planning rationality could be dismissed either as an attempt at rationalizing the balances established in the form and rationality of power or as the scientifically and historically failed attempt to develop a form of total [scientific] planning» [29] (p. 7). Here, I'd tend to believe in the second statement.

[4] Mazza distinguishes 'territorial governance' from 'spatial planning' [31]. The former «encompasses all activities and processes through which statutory and non-statutory plans and policies are negotiated, drafted and adopted» (p. 519). The latter «refers to the knowledge that provides the principles underpinning the preparation of land use plans, planning policies, and the undertaking of development control activities» (p. 514). In so doing, the author distinguishes the political nature inherent to spatial planning ('territorial governance') from the technical knowledge available to the expertise ('spatial planning'). The latter, it should be noted, «can be conceptualised as comprising spatial models, rules (or norms), and a technical language combining the two – a form of knowledge that historically constituted a disciplinary field, even though over the last few decades its features have faded to the point of becoming hardly recognisable» (p. 515).

the progress of analytical activities, such as urban and regional studies. Therefore, the justification produced by the planner cannot always be based on a satisfactory, acceptable explanation, for example in terms of classical rationality and of definitive conditional relations» (p. 38).

From such words it is possible to deduce at least two interesting considerations. First, urban decision-making is incompatible with scientistic postures which, relying on scientific evidence, promote increasing automation in planning and policy implementation. Consequently, the role of experts lies not so much in *explaining* (using data, simulations, models) as in *justifying* a certain decision. The sphere of communication thus assumes significant importance [4]. The second worth noting aspect is that, because of the «weak knowledge on which the planning choices are based [...] the justification produced by the planner will not always be based on satisfactory explanations» [5] (p. 39). Every justification, Mazza argues, is a partisan expression – that is, it is *partial* in that it is *advocacy*. All in all, the argumentative nature of urban decision-making also justifies the technical content of planning and, ultimately, the techno-scientific rationality that feeds it. In fact, «in the absence of justification, technical planning activities make no sense. It is not possible to define their technical content, their professional integrity, they are only trivial and immoral coverage of legitimate political discretion» (p. 40).

Yet, in the light of increasingly widespread *datafication* [14], nowadays the impression is that automation (guaranteed by the data that feeds AI) is used to make unproven and, as such, non-negotiable decisions. The robust quantitative analysis, by itself, seems to guarantee evidence about the wisdom and sustainability (which is economic, environmental, and social) of a certain decision. Considering this, let us dwell on the following question: since the discretion of choices implies a technical, political, and ethical responsibility on behalf of the planners, in the absence of such discretion what about the argumentative dimension of the urban decision making? Legitimation besides seems to remain in the background, somehow marginal. Within the argumentative perspective [32], the experts' legitimation lies in the ability (and concrete possibility as well) to provide convincing argumentations in support of one decision rather than another. In the absence of this possibility, the legitimation of experts is de facto separated from the responsibility they may exercise in shaping the decision-making process. Being mostly limited to data collection and analysis, the role of experts is no longer justified by the soundness of the argument but by the breadth of the database supporting (model and simulation-based) predictions.

This consideration opens-up many possible reflections. The most interesting, probably, regards the inherent limitation to today's urban modeling as the basis for 'specific predictions' – rather than 'qualitative predictions' [33]. Given the complexity of contemporary urban processes [34, 35], then, the idea that decisions can be made relying on 'algorithmic governance' [13] is at least incautious. More generally, it seems reasonable enough to agree on the fact that, while avoiding 'techno-phobic' drifts, we cannot but evoke a greater balance between quantitative and qualitative methods. Not so much in the name of multi-disciplinarity (which risks falling into rhetoric) as in epistemic plurality [36].

5 Urban AI and the 'Techno-Triumphalist' Temptation, Amidst (Errors of) the Past and (Risks of) the Future. Final Remarks

The disciplinary discourse on artificial intelligence, as it emerges from the most recent academic literature[5], leans for a certain caution with respect to the spread of this technology (and its multiple applications) in planning practices. This is perhaps due to the fact that the knowledge of AI technology among planners is still low [17], and this leads to a certain prudence. On the other hand, proponents of 'new urban science' – among whom Michael Batty is worth mentioning – promote research in the field of AI and in doing so do not express special concerns. Rather, the attention of academics seems to be animated by an unspoiled curiosity, almost certainly reinforced by the reassuring confidence in techno-scientific progress. Hence, relying on the conception of AI as a mere 'tool', the experts seem to opt for a pragmatic acceptance of the paradigm of automation. According to Batty [37], AI is expected to «inform the plan-making process in much the same way computer tools of many kinds lie at the basis of planning support systems» (p. 5). Such optimism – which is here referred to as 'techno-triumphalism' – endorses the quest for «automating functions within cities, and within the wider context of their urban planning» (p. 5). By relying on an instrumental conception (which, as such, is perniciously reductive) of AI technology, this posture delivers a sort of «technological solutionism in which digital technologies are positioned as the answer to all issues, regardless of context and history» [13] (pp. 209–210).

Indulging in such a belief signals the main-stream propensity towards a scientistic understanding of AI, which should be framed within a wider revival of scientism in planning (as the rise of the 'new urban science' seems to confirm). In an uncertain and constantly changing scenario such as the current one – where the pace of techno-scientific innovation driven by artificial intelligence is unmatched with respect to our ability to understand its impacts –, it is likely that planners risk repeating the mistakes of the past. I refer to the 'scientific turn' of the 1960s and 1970s – here already mentioned. To think that, today much more than yesterday, technology alone can revolutionize the discipline (or even grant it that epistemological unity planning so long pursued) is at least myopic. The promotion of the paradigm of automation in urban decision-making, if extended indiscriminately, is likely to resurrect scientistic postures that were considered outdated – and (provisionally) replaced by an argumentative conception of planning. In this perspective, as claimed by Mazza, spatial planning escapes the logic of automation. Nevertheless, the 'techno-triumphalist' stance seems to encourage the spread of powerful new disciplinary rhetoric that, while exalting the paradigm of automation, seem to underestimate its effects in terms of technocratic governance [38].

In this I see the main risk related to the spread of AI technologies in urban planning: that is, the emergence of unprecedented technocratic-oriented and automated decision-making models. Besides, a technocratic usage of AI undervalues its real epistemological, political, and cultural impact. As a matter of fact, like every technology, also AI is deeply conditioned by the biases of those who have been shaping it (beginning more

5 For a concise and up-to-date literature review I refer to the paper mentioned above, written by Sanchez, Shumway, Gordner and Lim [17] published in the *International Journal of Urban Sciences.*

than 80 years ago) and that are reflected in the forms of the *new ability to act* expressed by this very technology, to quote Floridi [1] again. Awareness of all this should lead planners to reconsider their understanding of artificial intelligence as a 'neutral' tool, so to avoid falling in the errors of the past. Indeed, without a careful weighing of both its potentials and risks, an unbiased belief in AI technology as driver for change in planning is vain – if not deleterious.

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AI-Based Tools to Enhance Visioning and Urban Decision Making in Future Deliberative Processes Within the Web-Platform Decidim

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Abstract. This contribution takes into consideration the possible integration of AI-based tools for the production of images within bottom-up decision-making processes, focusing urban planning when this involves the use of web platforms – for deliberative processes – like Decidim.

Using Decidm, the only platform with open-source code useful for deliberative processes, and integrating in the use of the web platform a tool for the generation of images/ project vision based on Artificial Intelligence, this paper examines possible future scenarios in which AI-based tools play a role in deliberative processes in participatory urban planning.

The contribution compares three of the main competitors among the different tools for generating images based on diffusion models, capable of processing and/or modifying images by predicting the position of individual pixels, to select the more suitable one to be integrated in a participatory process. Finally, by sytemising the Decidim platform and the AI-based Stable diffusion tools, the contribution exposes three possible integration scenarios taking into consideration in which steps of the "participation ladder" the participatory process would be positioned.

Keywords: AI-based tools · Decidim · social innovation · participatory action-research · deliberative processes

1 State of the Art in Participatory Urban Decision-Making Process with the Arrival of the New AI-Based Tools and Web-Platforms

The wide and rapid spread of artificial intelligence-based tools for the generation of text, images and sound is pushing European legislation to take measures that set criteria and limits on their use, and the AI act is the first European legal framework to regulate the use of such instruments (*AI Act | Shaping Europe's Digital Future*, 2021). Keeping in mind the new European legal framework, and the recent literature about design with AI-tools (Chung et al., 2023; Jaruga-Rozdolska, 2022; Ploennigs & Berger, 2022), this paper wants to take those tools that are able to convert the textual proposals of citizenship

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and stakeholders into project visualizations (in the preliminary phase) to help decision-making and design on the urban scale. In addition, this paper considers the integration of image generation tools within open-source web platforms such as Decidim that are used by the public administration for drafting participatory budgets or participatory urban planning.

These tools have recently distinguished themselves for their ease of use, in fact it is enough to write a text or rather a “prompt” to generate an image. Behind this ease of use are complex mathematical models, called “diffusion models”, that allow the translation of textual “prompts” (Brown et al., 2023) into images.

Finally, these “diffusion models” are the same as those underlying the text generation tools[1] and that they are trained to predict the location of pixels in an image rather than words in a sentence (Brown et al., 2020).

Among the processes that are increasingly trying to incorporate AI-based tools, for the automation of some phases, there are process related to urban decision-making. One of the first hints in the literature of this contamination are already found in the last decade, when the AI-based tools and “diffusion models” behind them were less refined (Fernández-Martínez et al., 2018). Fernández-Martínez et al. (2018), using the tool called “CoGovern” in the context of a citizen lab, proposes “a decision-making process that incorporates artificial intelligence techniques into a collective decision process and whose result is mainly based on standard optimization techniques rather than vote-counting”. However, if it is true that this latest proposal has the potential to be integrated into urban decision-making, it brings with it a series of risks inherent in current tools based on artificial intelligence. Specifically, AI-based tools bring with them a series of biases inherited from the amount of data used to train AI-tools (Bender et al., 2021). Lastly, Fernández-Martínez et al. (2018) recall how the use of online platforms such as Decidim do not guarantee an increase in public engagement. In short, also according to Robinson & Johnson (2023), the citizens who were already active are the same ones who use online platforms and new tools for public participation in decision-making.

In the following sections of this contribution, three scenarios of application of AI tools in participatory processes are discussed. It is also noted that among multiple AI-based tools, only three in particular have been selected given that, to the best of the writer’s knowledge, little literature exists that deals with and compares such tools for the generation of images in design processes (Bova, 2023; Chung et al., 2023; Jaruga-Rozdolska, 2022; Ploennigs & Berger, 2022). Furthermore, again to the best of the writer’s knowledge, only recently have these tools been tested in preliminary processes of participatory urban design. In this regard, here is a mention of the experimentation of the use of Midjourney in the workshop “ The city and its signs: urban regeneration in creative ecosystems”, held Turin in April 2023, where participants were able to convert verbal proposals into visions of projects for urban public spaces (AIGU, 2023).

The choice of Decidim as the online platform in which this paper proposes to integrate AI tools, in addition, to date, is given by the fact that this is the only platform for public engagement with open-source code traced in studies on the “platformization of public participation” (Robinson & Johnson, 2023, p. 76). Moreover, at the state of the art, only

[1] An example among all is the diffusion model called Generative Pre-trained Transformer (GPT) (T. Brown et al., 2020) together with its evolutions to date.

recently literature is available on the discussion of the Decidim platform in the era of artificial intelligence (Barandiaran et al., 2024a, 2024b, 2024c) and this study fits into this gap.

Finally, as reiterated in the existing literature on Decidim, use must be accompanied by the figure of the architect/planner who - in the urban decision-making process - increasingly takes on the role of facilitator and participant:

> *"the ways in which planners have positioned themselves in relation to residents are evolving. Professional planners have moved from holding a perceived monopoly on expertise towards acting as facilitators, and now an emerging professional role as active participants in undoing systemic patterns of colonialism and racism (Goetz et al., 2020). Furthermore, practitioners and researchers continue to develop and implement new techniques and processes for participation and engagement."*
>
> (Robinson & Johnson, 2023, p. 74)

After this introduction, with the aim of outlining possible integrations of AI-based tools in the Decidm platform, the paper is structured as follows: methodological framework for the selection of tools based on artificial intelligence to be integrated in participatory design; performance of tools in the empowerment of citizenship involved in decision-making processes in Decidm, in three possible integration scenarios of the selected tool; discussion and conclusion.

2 Methodological Framework: The Use of Arnstein's Participation Scale to Evaluate Three Possible AI-Based Tools for Generating Urban Design Visions in Decidim

As mentioned in the previous section of this contribution, the use of AI-based tools or the use of web-platforms does not guarantee an increase in the engagement or empowerment of citizens in urban decision-making (Robinson & Johnson, 2023). Furthermore, numerous problems linked to the use of data have already been raised in the literature given their nature and how they are collected:

> *"Beyond the collection and ownership of data, there are potential challenges with the quality of data that underlies platforms, as it may be biased, non-representative, or inaccurate (Green,* 2019*; Matheus et al., 2020). The same is true of algorithms, through which decision- making happens within an impenetrable black box, leading to a lack of accountability and transparency with respect to outcomes (Kemper & Kolkman, 2019)"*
>
> (Robinson & Johnson, 2023, p. 73)

As recalled by Robinson & Johnson, both the data and the algorithms - at the basis of the functioning of Natural Language Processing (NLP) - bring with them biases that can influence the result as well as lead to greater marginalization of minorities given that they are poorly represented in the data (Dickinson et al., 2019; Robinson & Johnson, 2023, p. 73; Wiig, 2016).

> *"Additionally, there are concerns around the proprietary nature of the algorithms behind the platforms and the opaqueness of their systems [...] Research suggests that this may lead to the amplification of existing inequalities experienced by underserved communities, due to a higher likelihood of those communities not being appropriately represented in the data or adequately considered in the creation of algorithms [...] Given this tension, the ways in which urban platform tools privilege data quantity over quality require further attention"*
>
> (Robinson & Johnson, 2023, p. 73)

In participatory processes, the introduction of AI must be carried out with caution (Fernández-Martínez et al., 2018, p. 4), given the risks mentioned above. Despite this, there are virtuous examples in which the data collected through the platforms have actually improved the decision-making process by making it data-driven decision-making:

> *"Platform urbanism tools present new opportunities for government. The data plat- forms collect can offer governments the ability to use analytical tools to uncover new local insights that support data-driven decision-making (Gessa & Sancha, 2020), and potentially enhance two-way communication between citizens and government, increasing openness, access, and transparency (Gagliardi et al., 2017; Janssen et al., 2012). There are also examples of increased data collection through platforms leading to improved and more efficient service delivery and more informed public policy-making (Höchtl et al., 2016)."*
>
> (Robinson & Johnson, 2023, p. 73)

To help architects and planners in the decision to include AI-based tools in the urban decision-making process, this study brings attention to the role of the architect/planner in to be a facilitator of the decision-making process. To the facilitator, as well as expert and participant in the urban decision-making process, this study proposes the evaluation of three AI based Tools for the generation of images/vision in the urban decision-making and urban design processes, based on their declared characteristics[2] and Arnstein's "ladder of participation" (Arnstein, 1969).

> *"can AI expected always to enhance participatory processes? We must be prudent about the most suitable application scope of AI when considering democratic processes, since there are many AI techniques, and we cannot foresee all the consequences of introducing general AI in our everyday political life"*
>
> (Fernández-Martínez et al., 2018, p. 4)

[2] The study takes into consideration the characteristics of the three tools, as stated in the literature (Chung et al., 2023; Jaruga-Rozdolska, 2022; Ploennigs & Berger, 2022) that compares them but without evaluating their applicability in participatory and/or urban design processes tools.

2.1 Positioning on the Participation Scale: Three AI-Based Image Generation Tools Compared

Similarly to the contribution produced by Robinson & Johnson (Robinson & Johnson, 2023, p. 73) which considers six useful tools from the urban technology platform, this contribution compares three AI-based tools to enhance public participation in urban planning (Table 1). The indicators in Table 1 are established on the basis of the macro characteristics of the three instruments already recognized in the literature (Jaruga-Rozdolska, 2022). It should also be noted that this evaluation is useful if one wants to integrate these tools within methodologies for participation and social engagement (Moulaert & MacCallum, 2019; Van Den Broeck et al., 2020) pursuing equity and with the aim of getting as high as possible on the participation ladder (Arnstein, 1969).

Below, in Table 1, the three competitors for the production of images through the entry of textual prompts are compared.

Table 1. Comparison between the 3 competitors in image generation by entering prompts and reference images. The information in the table is extrapolated from the relevant websites (*DALL·E 2*, 2024; *DALL·E 3*, 2024; Midjourney, 2023; *Stability AI*, 2024)

	Midjourney	Dall-E	Stable diffusion
High degree of ease of use	✓	✓	
Free access		✓	✓
Open source code			✓
High quality of the result by providing only the prompt	✓	✓	
High possibility of customizing results (e.g. through the use of Low Ranking Adaptation)			✓
Possibility to perform an outpainting on an inpainting	✓		✓
Online use	✓	✓	
Active prevention against the use of offensive language and words in writing prompts	✓	✓	
Photorealism	✓		✓

From Table 1 it can be deduced that Midjourney and Dall-e are the easiest to use, and that if integrated into Decidim they can help citizens quickly convert textual proposals into visions in an intuitive way[3]. Again from Table 1, it can be deduced that the tool with greater ease of use and best result is Midjourney. However, despite the rapid evolution of this last tool, it must be taken into consideration that its source code is not open and that it

[3] This consideration also applies to the integration of these tools in decision-making processes based on participatory action research methodologies (world café, photovoice, walk and talk ecc.).

brings with it an old critical issue typical of the concept of smart cities: the privatization of services, the consequent loss of empowerment by citizens (Robinson & Johnson, 2023) and the descent down the ladder of participation (Arnstein, 1969) (Fig. 1).

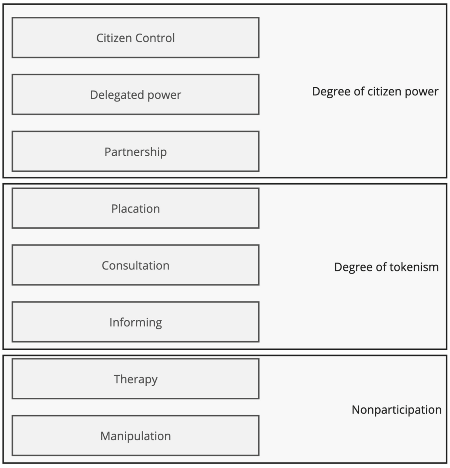

Fig. 1. Graphic re-elaboration of Arnstein's ladder of participation (Arnstein, 1969).

By removing Midjourney, for the reasons mentioned above, the differences between Dall-e and Stable Diffusion (SD) reported in Table 1 are examined. Between the two tools aforementioned, only SD have an open, visible and editable source code with the possibility for public administration to integrate the expertise for their management over time[4]. Given the ease of use, the choice of the tool to integrate into Decidim for a participatory process should fall on Dall-e. Despite this last consideration, the tool with the most potential in the visual quality of the results is SD. SD offers the possibility of training (deep learning) and calibration (Low Ranking Adaptation) of the drawing style[5] (D. Brown et al., 2023), as well as the possibility of starting from reference images (Fig. 2) and performing outpainting[6] and inpainting on images (Bova, 2023; Jaruga-Rozdolska, 2022) as well as passing lines from specific points via control-net[7] (Brown et al., 2023) increasing user control.

[4] I.e. without the need to delegate the task to a private body.

[5] For example, it is possible to calibrate Stable diffusion through a LoRA (Low Ranking Adaptation) which ensures that images are produced with the style of a specific architect (Zaha Hadid, Renzo Piano, etc.) (D. Brown et al., 2023).

[6] By "outpainting" we mean the possibility of generating (on the basis of a prompt) images in continuity with a reference image and which are an external extension of it. By "inpainting" we mean the possibility of generating, on the basis of a natural language command (prompt), an image within a reference image which then replaces a portion of it.

[7] Control-net is an SD plugin that allows to pass certain lines from certain points, this plugin is still in a early stage of development but it is possible to recognize its potential for the field of technical drawing with the use of AI-based tools (D. Brown et al., 2023).

SD is the choice suggested for its versatility and the possibility of being integrated into the platformization of civic participation (Robinson & Johnson, 2023), furthermore its being "open" (like Decidim) reduces the risk of leading citizens into "non-participation" (Fig. 1).

Fig. 2. Example of vision generation for participatory urban design, the photo in question comes from a participatory design experience with the use of photos and textual proposals given by citizens in the Grecanic area of Calabria (Italy) (Bova, 2023)

3 Three Possible Application Scenarios of Stable Diffusion in Decidim for Participatory Processes Related to Urban Design

In the platformization of urban decision-making, Decidim is the platform that potentially guarantees the greatest degree of empowerment to the community (Robinson & Johnson, 2023). This contribution, given the considerations set out in the previous sub-section, wants to propose the use of Stable Diffusion (SD) within platformization and in particular as a possible component of Decidim[8]. This proposal also derives from the particular malleability of Decidim:

> *"And, most notably, Decidim is the only tool, through its design, license, and structure, that potentially allows residents to evolve the tool through creating new modules. This open-source model allows Decidim to more closely align with*

[8] "Decidim helps citizens, organizations and public institutions self-organize democratically at every scale." "Decidim is a platform for citizen participation made by the people and for people. Its source code is open and can be inspected, modified, and enhanced by anyone. The Decidim software is covered by the AGPL license." (*Decidim*, n.d.; Robinson & Johnson, 2023).

the principles of open government, that is, that tools and processes of government be open to inspection by all impacted by the decisions made (Barandiaran et al., 2018). In this way, rather than requiring the corporate platform owner to develop or adopt any unique user needs or context, the open-source nature of Decidim allows for potential customization of a local implementation, drawing on premade modules from other governments or implementations, or through true custom development of a new module"

(Robinson & Johnson, 2023, p. 80)

Among the possibilities offered by these tools, the scenarios in which facilitators and/or architect planners can be involved in participatory processes can take shape as well as the possibility for the community to take part in a participatory budget (possible with Decidim). From here, taking as an example the renovation or urban regeneration of a former industrial area in a given municipality, at least 3 scenarios open up:

1. The facilitators, in addition to managing the positioning of the modules and the active moderation of the language, fully manage the use of the tools, collecting the verbal proposals online (on Decidim) and offline in public meetings as in Figs. 3 and 4 and then converting them into vision/images;
2. The facilitators only manage the positioning of the modules and the active moderation of the language, citizens can produce their own visions/images directly from Decidim and share them with other citizens to fuel public discussions;
3. Interested citizens can, through Decidim, have the possibility to select their own facilitators and can – given a set budget as well as for scenarios 1 and 2 – conduct a decision-making process.

In all three scenarios the possibility of inserting SD into a participatory budget is taken into consideration; this possibility by Decidim takes citizenship outside Arnstein's "degree of tokenism" (Arnstein, 1969) (Fig. 1).

In scenario number 1, the inclusion of SD among the Decidim modules tends to bring the participatory process to the lowest "degree of citizen power" with the control and moderation of the intermediate (vision) and final (project) results in the hands of facilitators and public administration.

In scenario number 2, the intermediate result (vision) is in the hands of the citizens, the moderation and implementation of the tool in the hands of the facilitators, and the final result is then in the hands of the public administration according to the indications of the citizens. The second scenario potentially brings the process to the second of the "degrees of citizen power" (Fig. 1).

In the third scenario, through Decidim, it is possible for the community to select its own facilitators (for example based on specific skills in urban design or in the management of the platform itself) and decide how to use the budget. The third scenario brings the process back to the second of the "degrees of citizen power" giving citizens more decision-making power than in the second scenario.

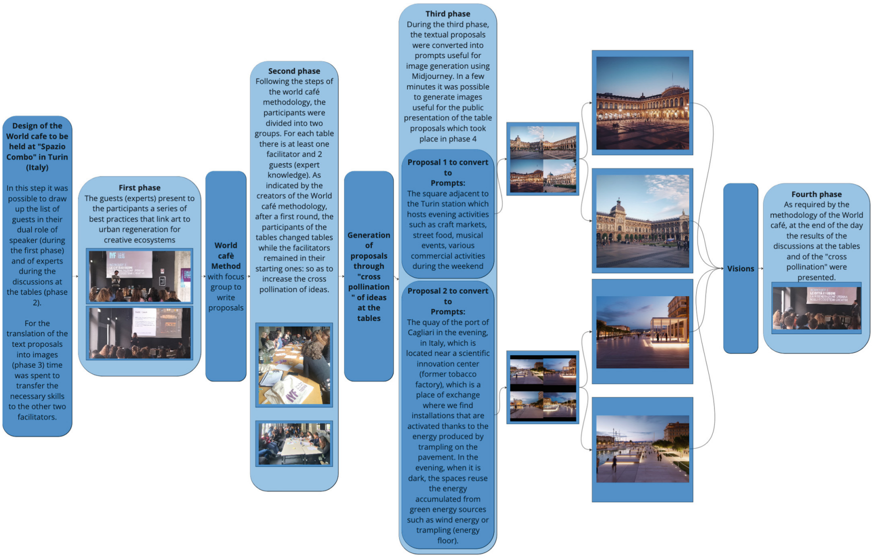

Fig. 3. Co-visioning process designed for the workshop "The city and its signs: urban regeneration in creative ecosystems", based on the methodology called "World Café" and with the addition of the Midjourney tool (Bova, 2023)

Fig. 4. One of the results of the co-visioning process took place during the workshop "The city and its signs: urban regeneration in creative ecosystems" held in Turin in April 2023. From the textual proposal a vision of the proposed urban space was generated (Bova, 2023)

4 Final Considerations: Stable Diffusion and Decidim Between Risks and Opportunities

In the platformization of urban decision-making, the risks that emerge are almost the same as those that have been exposed in the literature for "smart cities": mainly the risk of privatization of services (Robinson & Johnson, 2023). Combining the platformization of urban decision-making with the use of AI-based tools to contribute to urban decision-making brings with it further risks as well as the possibility of providing empowerment to the community and/or speeding up the participatory visioning process which precedes the other design phases in urban design (and architectural design) (Bova, 2023; Jaruga-Rozdolska, 2022; Ploennigs & Berger, 2022). The risks brought by these AI-based tools are linked to the biases that these tools can bring with them following the deep learning necessary to put them into operation, i.e. they can only bring the result towards images (or texts) used for the training that they time may be affected by human cognitive biases.

In the generation of texts, models such as GPT-3 diffusion and subsequent evolutions lead the result towards what is most represented in the data (Bender et al., 2021). In the case of architectural design, does SD lead the result towards trendy rather than prompt-responsive architecture? This risk can be mitigated if: 1) the public administration internalizes the expertise for managing the platform used and the tool based on artificial intelligence; 2) the AI-based tool, such as SD, has public and manipulatable source code for more transparent control; 3) the tool based on artificial intelligence, such as SD, has the possibility of being trained and calibrated (via LoRA) for the specific purpose aimed at by a given urban decision-making process.

It should be noted that these last 3 measures serve to mitigate risks rather than eliminate them. Despite this, indicating the critical issues in the use of these tools remains a constant exercise (Radhakrishnan, 2023) given their rapid evolution which could offer both possibilities to mitigate them - as seen in the case of Stable diffusion - and to increase them. In the last instance, it is pointed out that this study only looked at a section of the possible participatory design process with Decidm, further studies may explore the impacts of these new technologies at other stages such as economic assessment (Abastante et al., 2022).

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Varieties of Social Impact Investing. A Philosophical View

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Abstract. Social impact investing (SII) has been a growing trend in finance for more than a decade. SII is defined as an investment aimed at "positive, measurable social and environmental impact" besides financial returns. In this paper, we point out that this measurability requirement can be problematic if the uncertainty is severe. We then provide a taxonomy of different types of impact investing based on a distinction between financial impact (FI) and social impact (SI) returns. Acknowledging the variety of impact investing can shed light on the practice of SII and indicate when forms of greenwashing or retrofitting are possible.

Keywords: Social Impact Investing · Uncertainty · Philosophy of Social Impact

1 Introduction

Social impact investment is usually defined as an "investment made with the intention to generate positive, measurable social and environmental impact alongside a financial return" (OECD 2015). Needless to say, given the complexity of each of these factors, they can be the object of a theoretical and philosophical analysis. First of all, the impact of an investment must thus be positive, and this is an evaluative judgement. Then, in order to avoid purpose-washing or retrofitting and foster integrity and legitimacy (Findlay and Moran 2019), the impact is assumed to be obtained in an intentional (i.e., non-incidental) way, in the sense that purposes and indicators should be fixed *ex ante* and be evaluated *ex post* (Calderini et al. 2018; on the interplay between values, purposes and indicators see Lami et al. 2023). It is also assumed that impact investment must be an investment in the real economy that would not have otherwise happened. More precisely, an investment only has an impact if the social outcomes surpass what would have occurred otherwise. This property is called "additionality" (Busch et al. 2021) and is based on some counterfactual assumptions that can be difficult to evaluate. A further crucial aspect of impact investing is measurement. The basic idea is that risk, return and impact must be measured and this may be particularly problematic since not all types of uncertainties involved in these concepts can be always measured or even formalized (Hansson 2022). For instance, this is particularly the case when trying to measure social impact, given its complexity and value-laden factors. Finally, the

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financial return is an essential feature of an impact investment and differentiates it from charity. The connection between financial and social returns, as well as the interplay between social and financial risk, remains a topic of discussion in the literature. Investor preferences are commonly characterized as either *impact-first*, where the primary focus is on optimizing social impact while maintaining a certain level of financial return, or *finance-first*, where the emphasis is on optimizing the financial return with a certain level of social impact (Findlay and Moran 2019). Nevertheless, impact investing is often used as an umbrella term, facing the threat of insufficient classification and clarity. Indeed, investigating the intricacies of impact investing's diverse landscape poses a significant challenge for the field and the need for a more nuanced understanding of the relationship between financial returns and societal impact has been recognized (Goldman and Booker 2015). Our chapter tries to shed light on some basic elements to be considered when evaluating different types of social impact investments that may help us create a taxonomy in order to better evaluate and rank them. Section 2 explores the role of different forms of uncertainty for impact investing, while Sect. 3 proposes our theoretical framework for the different types of impact investments. Finally, Sect. 4 concludes the paper by highlighting validity and limits of the theoretical dimension of impact investing.

2 Social Impact and Uncertainty

Investing is always a risky endeavor, as returns are not certain. When the possible outcomes are identifiable and it is possible to assign meaningful probabilities to their occurrence, the investment happens under conditions of *risk*. However, very often investments have unforeseen consequences, as well as returns with unknown or unspecified probabilities. These are situations of *severe uncertainty*, where the information available to the agents making the investment decisions is particularly scarce. In the context of social impact investment, severe uncertainty may be especially widespread: uncertainty over the financial impacts of an investment sums with uncertainty over its social impacts, which may be harder to predict precisely.

This makes the measurability requirements of impact investing potentially problematic. The need to quantify the possibility of occurrence of some impact, when there are no meaningful probabilities to assign to it, may lead to distorted representations of uncertainty. Moreover, while monetary values provide a natural quantitative measurement of financial impacts, it may be harder to find natural and uncontroversial measurements of social impacts. In cost-benefit analysis, for instance, the necessity to weigh together both monetary and non-monetary costs and benefits is typically met with the instrument of monetization, by which goods and services with no direct market price are assigned a monetary value. However, this practice may be particularly unreliable for the intangible goods that are at the core of social impact (Hansson 2007; Hirsch Hadorn 2022).

Social impact investing can be subject, in particular, to different types of uncertainty. The investor can be uncertain about whether an investment strategy will have the expected impact and about the size of this impact. These uncertainties can be considered as *empirical* uncertainties. However, there can also be *parametric* uncertainties at play. As we saw, the impact of a specific investment must be measurable. This requires choosing appropriate *indicators*. For example, CO2 emissions are often used as a proxy for environmental impacts. The investor can be uncertain about whether all the relevant indicators have been considered and whether the value of these indicators has been measured correctly. Finally, the investor can also be uncertain about the investee's core values, that is, if the company will adopt a business strategy that is in line with the investor's own values. These three types of uncertainty may be more or less apt to be measured depending on the context.

In particular, we can distinguish between the following two types of decision situations where uncertainty can play a crucial role:

Case A: situations in which decision-makers must decide on how to act themselves; for instance, if, where, when and how to build an artefact or infrastructure, such as a bridge, a new metro station or a public hospital, and so on.

Case B: situations in which the decision-maker has to decide how to regulate someone else's decision on how to act; for instance, how to design planning rules and building standards that will constrain and channel the decisions of developers, architects, ordinary citizens, and so on in relation to the creation or transformation of artefacts (Moroni and Chiffi 2021, 2022).

We hold the view that the decision to perform impact investment is particularly felicitous in case A, where risks and impacts can be much more easily measured. Case A decisions are a type of decision where the decision-maker selects a specific action or sequence of actions to address a problem or achieve a goal. The decision-maker is typically the owner of the infrastructure, and the actor implementing the decision is aligned with the decision-maker. The possible outcomes of the intervention are listable, and some form of prediction is necessary. The space and time for potential actions are pre-determined, and the technologies used to transform the built environment are predefined. The success of the intervention is often measured by the level of utilization. Finally, the decision requires direct resource requirements, and financial and economic evaluations are commonly performed.

In Case A, clear boundaries are established, and the agent has direct control over outcomes. On the other hand, Case B is more focused on regulating the behavior of others. Fulfilling the measurability request for impact investing seems more straightforward in Case A. However, it is important to note that impact investing may also involve aspects of Case B, as its goal is also to influence the behavior of the companies in which one invests.

3 Types of Impact Investments

Let us assume a gamble such that an agent has to select between:

1) Receiving 100 $ for sure (certainty)
2) 50% of winning 200 $ OR 50% winning 0 $

Moreover, let us assume that the agent is risk-averse, a natural assumption in investing. From this fact, it follows that the agent may experience a reduction in utility from gamble versus certainty (see Fig. 1).

Let us call this reduction in utility ρ. One way to convince the risk-averse agent to accept the gamble is to offer her/him an increase in utility which is equal to ρ. However, if we interpret utility as choice-worthiness, i.e. a measure of the value of an action that is not necessarily confined to the subject's (economic) preferences but can also encompass the intrinsic (moral) value of the action itself (MacAskill et al. 2020), then utilities do not necessarily involve just a monetary counterpart. Indeed, discussing utilities helps sidestep the challenge of using monetary units to address diverse elements.

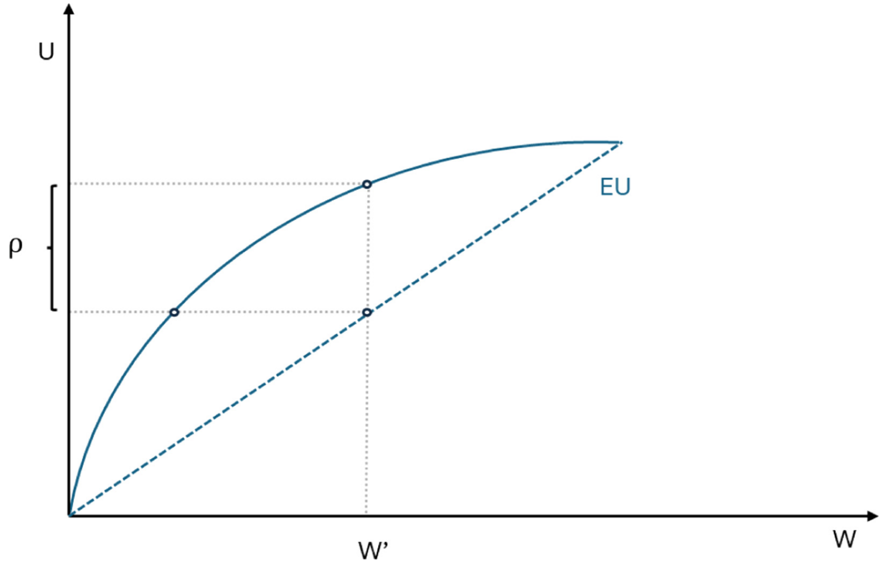

Fig. 1. The utility curve of a risk-averse investor: ρ identifies the utility required on top of the expected utility (EU) for W' to be a rational investment for the risk-averse investor.

From an intuitive perspective, we should be capable of convincing the risk-averse agent to accept the gamble if we can offer her/him an increase in utility which is equal to ρ.

From a strictly financial perspective, the utility interval ρ might be converted into a specific extra amount of money that we can offer to the agent to accept the gamble.

However, utilities when interpreted as a measure of the preference of a decision do not necessarily involve just a monetary counterpart. Utility here represents the choice-worthiness of a decision or action, which has at least two components (a monetary one and a social one). It is crucial in our perspective to adopt the concept of utility as choice-worthiness (MacAskill et al. 2020), taking into account a blend of financial, social, and potentially reputational factors.

For the sake of simplicity, let us assume that ρ may have two components: a financial impact (FI) and a social impact (SI). Let us also assume that we can use some common units for utilities expressing FI and SI and the environmental impact of an investment is here assumed to be part of SI. The idea is that the choice-worthiness of a decision can be justified not just by strictly economic reasons but also by social and environmental reasons. In a very simple case, we can imagine that the global impact of an investment (i.e., a measure of the choice worthiness based on financial and social impact) is FI + SI. More complex ways to put together FI and IS are possible in order to formalize the interplay between FI and SI, but we do not consider this now. We use 'social' here as a general term also encompassing environmental aspects. However, it might also be possible to distinguish these two components more precisely to enable more complex analyses.

Recall that ρ is the increase in utility that the agent should be offered to choose a gamble involving a risk over a gamble with a certain outcome. Based on ρ, FI, and SI, we can imagine different types of social-impact investing and differentiate them from other phenomena.

1. *First Scenario: General View*

   $\mathrm{FI} + \mathrm{SI} > \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} > 0$.

Cases:

(i) $\mathrm{FI} + \mathrm{SI} > \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} > 0$; $\mathrm{FI} > \mathrm{SI}$
(finance first)
(ii) $\mathrm{FI} + \mathrm{SI} > \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} > 0$; $\mathrm{FI} = \mathrm{SI}$
(same level of impact for social and financial investing)
(iii) $\mathrm{FI} + \mathrm{SI} > \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} > 0$; $\mathrm{FI} < \mathrm{SI}$
(social impact first)

2. *Second scenario: General Reduced View* (similar to a disproportionated risk adjusted return)

One could imagine a situation in which $\mathrm{FI} + \mathrm{SI} < \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} > 0$.

This situation is worth investigating. A possible way to treat this scenario is that the global impact can be considered in this case to be composed not just of FI and SI, but also of another kind of impact which may contribute to the choice-worthiness of a decision, for instance a reputation impact (RI). If we also consider RI, then we have the following cases:

(iv) $\mathrm{FI} + \mathrm{SI} < \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} > 0$; $\mathrm{RI} > 0$; $\mathrm{FI} + \mathrm{SI} + \mathrm{RI} \geq \rho$; $\mathrm{FI} > \mathrm{SI} + \mathrm{RI}$
(finance first)
(v) $\mathrm{FI} + \mathrm{SI} < \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} > 0$; $\mathrm{RI} > 0$; $\mathrm{FI} + \mathrm{SI} + \mathrm{RI} \geq \rho$; $\mathrm{FI} = \mathrm{SI} = \mathrm{RI}$
(same level for all types of impacts)
(vi) $\mathrm{FI} + \mathrm{SI} < \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} > 0$; $\mathrm{RI} > 0$; $\mathrm{FI} + \mathrm{SI} + \mathrm{RI} \geq \rho$; $\mathrm{SI} > \mathrm{FI} + \mathrm{RI}$
(social impact first)
(vii) $\mathrm{FI} + \mathrm{SI} < \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} > 0$; $\mathrm{RI} > 0$; $\mathrm{FI} + \mathrm{SI} + \mathrm{RI} \geq \rho$; $\mathrm{RI} > \mathrm{FI} + \mathrm{SI}$.
(reputation first)

Can case (vii) also be considered a social impact investing? We do not think so since it is mainly a reputational impact, but it is still rational since the global impact composed by FI, SI and RI is equal or greater than ρ. Likewise cases (iv)–(vi) might be rational choices since the global impact composed by FI, SI and RI is also in this case equal or greater than ρ but the main reasons for the investment are still social and financial. It is also worth pointing out that both financial returns and reputation impact affect the investor directly, whereas the social impacts of the investment affect a group that the investor may belong to or not. Therefore, it is likely that investors are more risk averse with respect to FI and RI than they are with respect to SI.

3. *Limit Scenarios*

Let us consider cases in which $\mathrm{FI} + \mathrm{SI} = \rho$; we have:

(viii) $\mathrm{FI} + \mathrm{SI} = \rho$; $\mathrm{SI} = 0$ & $\mathrm{FI} = \rho$
(financial investment)
(ix) $\mathrm{FI} + \mathrm{SI} = \rho$; $\mathrm{SI} = \rho$ & $\mathrm{FI} = 0$
(pure philanthropy)

Let us consider cases in which $\mathrm{FI} + \mathrm{SI} > \rho$; we have:

(x) $\mathrm{FI} + \mathrm{SI} > \rho$; $\mathrm{SI} > 0$ & $\mathrm{FI} = \rho$
(this investment is financially conservative)
(xi) $\mathrm{FI} + \mathrm{SI} > \rho$; $\mathrm{SI} = \rho$ & $\mathrm{FI} > 0$
(social impact is guaranteed but there is still financial impact)

Let us consider cases in which $\mathrm{FI} + \mathrm{SI} < \rho$; this is not rational. Still, if we include a RI in the global impact, we can model these scenarios.

(xii) $\mathrm{FI} + \mathrm{SI} < \rho$; $\mathrm{RI} > (\mathrm{FI} + \mathrm{SI})$
(reputation first)
(xiii) $\mathrm{FI} + \mathrm{SI} < \rho$; $(\mathrm{FI} + \mathrm{SI}) = 0$ and $\mathrm{RI} > 0$
(strong reputation first)

If we set aside reputation impact (RI), the taxonomy becomes simpler, but such impact may explain many concrete phenomena associated with impact investing. Certain factors might display a clear correlation; for instance, FI and SI might exhibit this behavior. It is possible that the relationship between FI and SI is not merely additive, and a different approach is needed to amalgamate them. At any rate, why is it advantageous to propose a taxonomy like this one? Because, when aiming to rank our investments, it is imperative to first understand their structure. When we mention “finance first” or “impact first”, we could be referring to markedly different scenarios, as evident from the taxonomy in which reputation may play a non-secondary role. Moreover, even if promoting reputation by means of investing can be something positive and desirable for a company or public actor, overreliance of reputation in investing can also be a possible hint to greenwashing and retrofitting.

4 Conclusion

A variety of different types of investments may hide below the simple distinction between (social) impact-first and finance-first investing. Impact investing assumes that financial returns and various types of impacts can be measured and evaluated together. This assumption is also justified in other economic methods, such as cost-benefit analysis.

This measurability assumption seems to be less problematic in Case-A decisions where risks and benefits are located in a specific region for a specific time (e.g., the decision to build a new bridge), and plausible scenarios associated with the decision can be listed in advance.

However, when decisions occur under severe uncertainty, this assumption can be more problematic. In light of this fact, we focused on impact investing related to Case-A situations. This choice is also influenced by the potential of AI systems. AI has the potential to enhance the capabilities of impact investors through the provision of advanced analytics, better risk management, automation of impact measurement, and facilitation of more informed decision-making. This, in turn, can contribute to the overall growth and effectiveness of impact investing initiatives. However, the purpose of AI use in impact investing usage is to support human decision-making rather than serve as a substitute for thorough research and analysis (Williams 2023). On the diverse roles of 'decision aid' tools and their interplay with the social and political components of decisions, see (Lami and Moroni 2020).

We have critically evaluated how the different components of impact investing may create a vast range of alternatives. Acknowledging the variety of impact investing can provide the proper foundation to rank investments belonging to the same *category* and indicate when forms of greenwashing or retrofitting are possible.

Our contribution is based on a theoretical perspective aiming to provide guidance and inspiration for a much more fine-grained analysis and evaluation of different types of impact investing. Finally, from our philosophical perspective, understanding the nature of uncertainty for social and financial impacts of investing is essential to comprehend the cogency of our evaluations in the social world.

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Can AI Build a City?

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Abstract. Generative Artificial Intelligence is already used to build urban simulations, but how should this technology develop to build *physical cities*? To address this question, this paper takes the art and science of city making as an extreme case to identify opportunities and limits in the use of Generative Artificial Intelligence technologies for physical design. The paper is predominantly conceptual in nature proposing an exploration of the possibility to use AI for building physical cities. Subsequently, a critical review of key concepts for city making is discussed for virtual and tangible worlds. The paper concludes with a discussion and remarks addressing the main lessons learned.

Keywords: generative artificial intelligence · physical design · virtual cities

1 Introduction

What would happen if, perhaps in the near future, Generative Artificial Intelligence (henceforth GAI) could *create* extremely complex objects such as "real cities" (i.e. physical, tangible collections of human artifacts)? The question here is not whether AI-generated cities could exist but how GAI could build cities that humans would like to inhabit or use. Current technologies allow GAI to directly create cities in the digital world (as digital twins, or in videogames; [1–4]), while cities in the tangible world can only be influenced by GAI systems (mainly used to support decision-making phases including e.g. geographical analytics, building concept design, engineering simulations; [5–7]).

Wondering if and how GAI technologies could directly shape human habitats may seem like a dystopian question. Nevertheless, taking seriously the transformative capacity of this technology (and its potential in optimizing costs and labour), passing the art and science of "city making" from humans to machines can be a reasonable scenario. The transfer of dangerous, dirty, heavy, or tedious work to a tool is "innate" to the idea of technology itself. Scholars already discuss GAI applications for building activities: streamlining construction timelines, cost reductions, and enhancement of human safety are just some of the many reasons sustaining the adoption of AI-driven technologies [8]. One could easily imagine how GAI can be useful to deal with many ordinary issues (e.g. self-building through 3D printing technologies) but especially to intervene in difficult conditions – for example, during natural and social emergencies (e.g. geological,

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climatic, warfare disasters) and in extreme contexts (e.g. contaminated sites, extreme temperatures and environments, places without light, atmosphere or heavy pressures, outer space, etc.).

This paper aims to take "city making" as an extreme case to identify opportunities and limits in the use of GAI technologies for physical design. Since this is a speculative discussion, the paper is predominantly theoretical although supported by empirical considerations. The paper is organized as follows. The next section explores the state of the art of GAI applications by interrogating the technology itself (i.e. Chat GPT in January 2024). Subsequently, a critical review of key concepts about city-making emerges in the discussions of both virtual and tangible worlds. The paper concludes with a discussion and remarks addressing the main lessons learned.

2 AI-Generated Cities: Fiction or Reality?

GAI is already used to build *digital cities*, but how should this technology develop to build *physical cities*? To address this question, let us imagine the following scenario.

First, let us say there is a GAI system that is a single/central "command and control" cabin (e.g. the mind) in charge of setting and monitoring the activities to run and develop a physical city.

Second, the extension of this GAI system is a multiple/diffused collection of machinery (e.g. the arms), carrying out the commanded tasks to achieve the main goal: making a physical city.

Here, we are assuming there is one main GAI system from which all construction activities descend. This scenario is not science fiction. Considering the digital world and construction activities of digital twins, "By leveraging distributed learning algorithms, multiple distributed twins can be trained over multiple locations, and then a centralized twin can be developed for models aggregation and global decision making" [9, p. 28]. This can be possible by connecting objects through communication networks (e.g. "Internet of Things") where information can be adjusted to achieve certain goals or enhance performances (e.g. energetic performance in buildings; [10]). Many scholars underline the traits of universality in GAI technologies, underlining their vast potential for applications also in the physical sciences [11]. It is not difficult to imagine that cost-optimization and meta-learning could make GAI systems great allies to build physical cities too. For instance, by modularly building entire buildings and infrastructures, creating real-time mapping by communicating autonomously with satellites, electrical substations, control units, sensors, etc. [4]. In this world, humans could even be both clients and end users of cities created based on "citizens' needs" or, rather, *prompts*. GAI may combine consensus-building and public engagement protocols for urban governance altogether, shortcutting "participation" costs and making democratic deliberation instantly available for anyone able to express their desires. Some users may want to create/prompt their dwellings from scratch, and others may also adapt or customize dwellings that were already there. Some people may want to learn by themselves, others may prefer to pay a group of experts to do the job. In these terms, the city created through GAI may not be too distant from the cities we inhabit today, and, in some ways, it may even be preferable (considering all the savings in labour and transaction costs). The tangible world is obdurate [12]. Humans find imaginative, physical, and normative constraints even before being able to intervene [13, 14]. What about GAI technologies though?

Let us now consider what current GAI systems can do in terms of "city-making". To understand this aspect, it has been asked to the most used and largely available GAI technology (i.e. ChatGPT) whether it is possible to build cities using GAI. Apparently, GAI systems understand the question "can you make a city?" only partially, interpreting its role mainly as a support system in decision-making and, therefore, an integration to planning activities.

First, in terms of data analysis, GAI systems can be used to: "*address challenges such as population growth, sustainability, and resource optimization*". This first group of "areas of work" can be explained by the large use and availability of demographic, traffic, and environmental data. As foreseen by Thrift & French [15, p. 326], this area is a reflection of the affirmation of a "spreadsheet culture" in contemporary society. It also emphasizes the ability to generate "*comprehensive models for city planning, ensuring optimal allocation of resources, efficient transportation networks, and sustainable infrastructure*".

Second, in terms of design (digital and physical), GAI systems can assist: "*in creating innovative, functional, and aesthetically pleasing city layouts*", through algorithms to "*optimize designs based on various criteria, taking into account factors such as energy efficiency, accessibility, and green spaces.*" ChatGPT adds that: "*The result is a city that adapts to the evolving needs of its inhabitants and the environment*". Here, needs and prompts are probably taken as synonyms.

Third, in terms of construction activities (AI-driven), GAI can "*optimize the building process*", specifically letting machinery and robotics be driven by robotics generative AI algorithms, while it "*can also revolutionize construction by creating intricate structures efficiently*".

Fourth, in terms of management, the GAI takes on the role of monitoring processes dynamically: "*AI-powered systems can anticipate and mitigate issues, ensuring the city operates efficiently and remains responsive to the evolving needs of its residents*". Being "responsive" seems the key to dynamism and adaptation.

Fifth, in terms of ethics, ChatGPT admits that: "*The integration of generative AI in city building raises ethical concerns related to privacy, equity, and job displacement. Addressing these concerns is essential to ensure that the benefits of AI-driven urban development are shared equitably among the population*". This last statement, although noble, sounds like a retreat from the self-promotive attitude of the overall discussion.

Finally, ChatGPT states that: "*Generative AI has the potential to redefine urban development, offering solutions to longstanding challenges and creating cities that are smarter, more sustainable, and adaptable*"; a series of particularly successful buzzwords in urban studies. The inquiry concludes with a catchphrase: "*The future of city development lies at the intersection of human creativity and artificial intelligence, promising a new era of innovation and efficiency in urban living.*"

It appears that ChatGPT (and probably GAI technology in general) exhibits "positivistic" tendencies. Population growth, attention to sustainability, and optimization of resources are all ambitions aimed at an idea of transformation that points towards efficiency. This can be the result of the discussion on smart urban governance [1, 2]. Note, however, that demographic stagnation or decay could be inconceivably "undesirable" for a GAI system because it would represent a loss of resources (e.g. information). More curious is the idea that a GAI system could understand what "aesthetically pleasing" means in general and specifically in terms of design (architectural, industrial, urban, etc.). While it is possible to formalize some "desirable canons" for objects in the world, it is not certain that GAI can genuinely understand the problem of human appreciation through *time* [16, 17]. For the rest, what ChatGPT tells is widely known, easily shareable, and, at times, rhetorical. Ethical considerations seem merely instructed from the outside (similar to Asimov's laws of robotics). The rest is mostly self-promotion.

3 What Makes a Physical City?

To address this question, let us identify some essential elements useful to define the main characteristics and fundamental problems of what we call here "city-making".

First, cities are portions of *space*: they occupy geographical areas (excluding other uses) while collecting objects, like buildings, that have areas in themselves. A GAI system would make physical *assemblages* connecting the information available at that moment (resembling the difficulties of "flat ontologies" approaches in geography; [18]). GAI systems could use all the solutions recorded in the history of architecture and engineering, proposing solutions normally considered onerous or risky if carried out by humans (e.g. building on steep or non-solid terrains). Therefore, more space could be made available also in less traditional ways. The only risk is that of underestimating how human preferences matter in the actual use of available spaces (think of Frank Lloyd Wright's waterfall house).

Second, cities are *agglomerated*; their elements are numerous, close, and often affect each other (think about e.g. traffic, population density, economic wealth). To date, GAI systems are used to solve or compensate for lack of data, as well as for real estate values in cities. In particular, the discussion revolves around how these technologies are useful for (i) filling informational gaps (e.g. missing, sparse data; [19]), (ii) processing large volumes of data (e.g. mixed-type, real-time data; [20]), and (iii) articulating values' attributions more transparently (e.g., open-access data; [21]). However, claiming a better computational capability does not necessarily correspond to a closer approximation to the "true" or "right" value of a good or a process (e.g. market process). This is because a significant portion of the information relevant to real estate processes is complex, not entirely formalizable, and/or transferable to a spreadsheet.

Third, cities host a *variety* of many unique elements. To date, GAI can generate different results from the same prompt, but, however different the outputs, they mostly remain clusters of pixels. In a future in which GAI systems could drive large-scale operations on physical sites, it is not certain that the variety of outputs would be the same as those obtainable digitally today. Both drivenness [22] and also originality will be lacking. Signs of exuberance or opulence (cost-ineffective) might be difficult to reconcile with the "rationalizing" nature of this type of technology (as it was for modernist tradition in the XX century). Unable to think "outside the box", GAI could build mild and repetitive environments but not necessarily unbearable for human living. As suggested in Mallgrave [23], artificial technicians cannot genuinely "get tired" or bored, which are underlying and fundamental aspects to the development of many human creative capabilities (e.g., movement, choice, inventiveness).

4 Discussion

Having questioned the possibility of building "real cities" in "tangible worlds" through GAI technologies, their production and reproduction still depend on space. More specifically, they depend on the material possibilities in which goods – even a city – exist [24]. In the tradition of vernacular architecture, the main concern was material availability; in the words of Banham [25, p. 15]: "In practical arts like building, it is not the original brainwave that matters so much as the availability of workable hardware, capable of being ordered ex-catalogue, delivered to the site, and installed in the structure." For David J. Chalmers [26, p. 442], in virtual cities the problem of space (or better, scarcity) does not arise: "Construction is easy too. Once a house is built, it can be duplicated elsewhere at little cost. Anyone can have a large virtual home in a wonderful location. The result could be virtual abundance." In this view, virtual cities emerge as an oasis of equality and distributive justice [26]. However virtual/digital or imaginary these elements can be, they remain related to a material substratum: the tangible infrastructure that supports their existence. Servers, computers, cables, etc., even when extremely compactable, continue to occupy portions of physical space, consume energy, and therefore continue to present scarcity problems. Even if humans want to move entirely into a virtual world, the infrastructure governing the virtual world will exist and expand if necessary [27]. Consider Bariah et al. [9, p. 28]: "heterogeneous networks [have] motivated the need for a significant network capacity expansion, in order to meet the demands of future dense smart cities". In a dystopia à la the Matrix, the virtual world will disfigure the tangible world to support greater computational power, making GAI systems a less "sustainable" solution than what is usually praised. See also [28].

Agglomeration does not represent a problem to be computed (as assumed to justify GAI applications in urban decision-making). Agglomerated environments, such as cities, *are* computational infrastructures in themselves. Information arises unpredictably from a pluralistic life, the experience of proximity, and spillovers [29]. Digital-worlds enthusiasts would argue that relationships between social communities can also be rich both in virtual worlds and outside of them [26, p. 404]. However, this statement is trivial if it is not also discussed in quantitative or comparative terms [29]. The amount of information that GAI can compute will always be less (and an approximation) than what natural intelligence can absorb by real-life experience [30], also because human logic evolves organically and spontaneously [5]. Thus, it is simply impossible to find optimum criteria based on combinatorial and automatic procedures; human deliberation remains irreproducible and central when making decisions [7]. Considering again the issue of prices, they encompass both explicit and enumerative/quantitative values, as well as implicit and non-enumerative/non-quantitative values [31]. Because of agglomeration, real estate values and their variations in cities arise from a dynamic combination of positive and negative externalities [32]. Perhaps, a GAI system could monitor negative externalities (as they are easier to define quantitatively; [33, 34]). However, positive externalities would remain difficult to be properly formulated and understood (thus continuing to be neglected; [35]). Even if capable of associating a value X to object A, artificial minds work in a computational, connectionist, and reductionist way [36]; non-artificial minds work in an embodied, embedded, extended, enactive, and affective way [the so-called, 4E type of cognition; [37–39], useful to understand both X and A, their spatial qualities and relations. A real estate analysis run through GAI can plot €100,000 as a reasonable price for an apartment (fine-tuning all the information available on its location, cadastral value, materials and technological equipment, energy classification, market trends, etc.). Nevertheless, GAI cannot determine, nor understand, if that price is a "good" or a "terrible" deal.

The variety of elements within cities is also a reflection of non-linear, irrational, out-of-average variations of information [7, 29, 40], unexpected both for a GAI system and for humans themselves. Think about the role that feelings, sensations, memories, preferences, and experiences play in the market price system [30]. The possibility that a property is haunted by ghosts or stories of bad luck has a concrete impact on the price system and market dynamics [41]. There is no specific formula to explain things like conscience, language, and feelings towards certain objects, places, and cities in themselves [16, 23, 30, 40]. GAI systems may inflate certain values more than necessary. Probably, the technology assumes trends as constant and/or because it cannot free itself from its premise: satisfying the users' desires (e.g. immediate rewards; [1]), even at the cost of lying [21]. Certain "quality" or "reality" checks are only possible experientially (based on the information collected on the spot; [30]), and/or based on human-centred considerations [7, 13, 42]. It is still under debate how sanctions apply to GAI systems; assuming that trials – but especially errors – contribute to innovations, the more work is delegated to GAI, the more homogeneous the distribution of opportunities will be with fewer peaks. GAI systems have all the capacity to make cities, especially cities that are "more affordable" (reducing construction/production costs). Many more people could live in houses *à la* Frank Ghery, but not *by* Frank Ghery (the original firm would raise the prices per square meter). In such a world, it is sufficient to have had "*a* Frank Ghery" to replicate over and over. It is not sure if, in this situation, humans would have lost all the reasons to compete against technologies and each other.

5 Conclusions

More and more people are amazed by Generative Artificial Intelligence (i.e. GAI). The term GAI indicates the ability of a system to create objects in response to requests based on learning and interpreting statistical information (Large Language Models). At the moment, GAI mainly engages in the creation and re-elaboration of digital media (e.g. images, music, texts, videos); all in all, pretty simple items. New ideas and questions emerge on the creation of complicated objects (construction projects, e.g. buildings and infrastructures; [8, 11]). Other studies instead focus on how to govern complex systems as cities; especially on decision-making models for planning (e.g. GeoAI; [4]). But few instead seem intrigued by the prospect of being able to completely delegate the entire construction of physical cities to GAI systems. This paper attempted to envision a (near) future where GAI contributes directly to the creation of physical cities. We discussed how GAI can work around different problems of space, underlining that both virtual cities and tangible cities pose problems of scarcity. For this reason, the prosperity promised by GAI systems could refer to a situation of perfect allocation, with few or some peaks of variety – possibly, hampering innovations in the long run.

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An Epistemological-Political Meta-Account of Digital Urban Twins

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Abstract. This theoretical contribution explores Digital Urban Twins (DUTs) through the lens of political epistemology, aiming to critically evaluate DUT conceptions and propose future research directions. DUTs, designed to generate forecasts for city governance, must address not only technological challenges but also political and social ones due to their public function, and specific theoretical frameworks are needed to manage these challenges. Political epistemology, which integrates scientific knowledge with its political context, offers valuable insights. Reviewing meta-literature on DUTs reveals a focus on social integration and governance issues, with case studies illustrating the complexity of DUT applications, emphasizing the need for interdisciplinary insights and participatory processes. This analysis suggests that political epistemology can inform DUT research, raising important questions and highlighting the intertwined nature of technical and social aspects in urban governance and technoscientific practices.

Keywords: Digital Urban Twin · Political Epistemology · Science for policy

1 Theoretical Contextualization and Methodology

The following theoretical contribution proposes to look at Digital Urban Twins (DUTs) from the perspective of political epistemology, with the aim to: a) critically illuminate DUT conceptions and bring out lines of future research, mainly in the form of questions for current developers of these tools; b) to demonstrate the hypothesis that political epistemology could be of use for DUT research.

The statement we begin with is that DUTs, being machines designed to generate forecasts beneficial to decision-makers for effective city governance, have a "public function", and therefore have to deal not only with technological construction issues but also with political and social challenges. If these challenges in the development and implementation of DUTs exist, purely technical conceptions of DUTs may overlook them: specific theoretical frameworks are instead necessary, equipped with tools to manage these criticalities. In other words, if technological development is guided by technical expertise, which expertise could inform the development of DUTs' public function? Furthermore, knowledge production must be considered, since it may not correspond to the production of technical knowledge guiding technological development. We believe that these questions can be tackled by a political-epistemological approach.

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Political epistemology refers to mode of inquiry involving various theories of scientific knowledge that adopt the methodological principle of not keeping scientific knowledge separate from its relationship with the political sphere (whether structural, ideological, or applicative). Among its focuses, we can find the examination of how science is used prescriptively to inform political action, the ideological implications of discourses on science, the interconnections between scientific practices, institutions and power structures, the social role of expertise [1–3].

For example, a theoretical proposal that can be considered within the field of political epistemology is the one formulated by Jerry Ravetz and Silvio Funtowicz, who refer to post-normal science (PNS) to describe situations where facts are uncertain, values are in dispute, stakes are high, and decisions are urgent [4, 5]. When knowledge is employed to contribute to governance processes, the framing and prioritization of issues inevitably involve value choices, questioning a rigid dichotomy facts/values. Moreover, the diverse perspectives involved in the collective sphere not only imply different values but also different bodies of knowledge and a pluralized expertise [6]. Within this framework, knowledge reconfigures itself around specific hierarchies of needs and aspirations, giving rise to distinct forms of understanding [7]. Finally, the urgency that characterizes the decision-making context prevents the plurality of hypotheses that can be formulated for new knowledge contents from being mobilized and properly tested. While influenced by scientific knowledge, political choices are therefore not methodologically scientific themselves; science intended for public decisions is always intertwined with conflicting values and interests, and the often necessary timeliness of decisions [8].

From this epistemological-political perspective, the promise of the DUT project to function as a knowledge producer about the future state of the city would find itself entangled in a decision-making and epistemological context that questions this very promise. For example, how would the DUT produce the kind of knowledge employed in governance processes if this knowledge involves a fragmented, multi-layered, value-laden, and potentially inherently conflictual production chain?

If this is the scenario painted by an epistemological-political driven approach, the conception of technoscientific activities that partly contributed to its emergence has made its way into the epistemological field for a few decades, especially since the interest of historians, sociologists, and philosophers has shifted from scientific theories to scientific practices, coupling epistemology with historical analysis [9], carrying out ethnography in laboratories [10] and reconstructing the evolution of science and technology in relation to the material conditions in which are situated. Is this the case of the interdisciplinary field of Science and Technology Studies (STS) [11], that considers technoscientific practices not isolated from the social world but as social activities themselves, where scientists, instruments, normative and institutional context interact in the production of knowledge. These interactions involve controversies, negotiations and forms of stability [12]. From this perspective, the problem of the DUT's public function becomes the problem to couple the development of DUT's technological functioning with an equally essential development of DUT's social functioning, that is, a functioning able to perform in contexts where, for example, values are in dispute. Would a political-epistemological angle, with the tool kit offered by theories such as PNS or STS, offer insights into such a development, or at least research questions worth exploring?

Before revisiting these questions, it is necessary to verify whether the hypothesis of DUTs concerns with the socio-political level is indeed documented in the literature, and if so, how. We choose to look at recent literature review articles on the subject. The analysis therefore moves on a meta-literature level, highlighting findings that these articles have in turn brought out from a more comprehensive research on what has been published on DUTs. Especially, the focus is on what the literature review articles found regarding DUTs' application as a support systems for urban governance, and whether social rather than technical matters were recorded, and of what kind.

Within this focus, two case studies are brought to attention from the literature. For both, it is seen what is meant by 'social' rather than technical and how the DUTs have been understood as a tool for knowledge-based governance.

2 Meta-Literature Review

Three literature review articles are analyzed: City Digital Twin Potentials: A Review and Research Agenda [13]; A systematic review of digital twin city: The adoption of urban digital twins [14]; Challenges of urban digital twins: A systematic review and a Delphi expert survey [15].

It should be noted that all three literature reviews point to research that is still in its infancy, and that after applying various filter criteria, the cases considered to be genuine urban twinning systems (in prototype or operational phase) are respectively 42, 22, 34 (see each article for their literature review methodology).

2.1 First Article

In Shahat et al. the integration of socio-economic components in the DUT is seen as the future research direction to achieve a completely mirrored city. Particular attention is paid to the Digital Twin of the city of Zurich, considered one of the most advanced in supporting administration in urban planning and decision-making processes. Concerning the public function of DUTs as a decision-making support, the thematic sets that the review identifies in literature are 'Planning and Prediction', and 'Integration and Collaboration'. The latter, with the subsets of 'integration between different domains', 'stakeholder participation', 'citizen engagement', and the 'open platform' depend, is associated with the largest number of articles analyzed. 'Planning and Prediction' instead refers to applications like 'policy evaluation', 'simulation', and 'what-if scenarios'. In planning, the most relevant quality seems indeed the ability to predict possible outcomes (what-if). Drawing parallels with fields like aerospace and manufacturing, where predicting the future behavior of the physical counterparts enhances performance, the city digital twin can similarly be employed to develop plans and scenarios for future urban operations. The challenge of a comprehensive digital representation of the city, which requires the integration of different databases and areas, is the reason to opt for different twinning systems (more or less in synergy) for different domains. In particular, a lack of awareness of contextual factors and social, economic and political structure and processes is emphasized as a drawback for a complete mirroring. The very quality of being an online networked service is then associated with the possibility of opening up the inclusion of different stakeholders in planning and design. The challenges for research are summarized in the ability to model contextual and socio-economic factors and to achieve mutual integration between the digital model and the physical city, so that cause-and-effect relationships can be one-to-one, considering that at the moment it is mostly the physical plane to interact with the digital one.

2.2 Second Article

Ferré-Bigorra et al. offers a categorization of the examined articles. One of the categories concerns the application of DUTs, starting from the users they are addressed to, which are predominantly public administrations. The prevalent use revolves around the maintenance of structures and infrastructure, but there are also cases where they are employed for urban planning. The most common models are those representing the 3D physical space, followed by meteorological models (whose databases are usually open source) and those of specific infrastructural networks. Also in this review, one of the main challenges that DUTs must face is the lack of interoperability and integration across different data domains, in addition to the high costs associated with real-time processing of data sources and computing requirements, leading to a trade-off between accuracy and efficiency.

2.3 Third Article

Lei et al. decide to categorize the findings of the literature review into two sets of challenges that research on DUTs must address during the phases of a digital twin's life cycle. On one side are the technical challenges, and on the other side are the non-technical challenges. Focusing attention on the latter, the issue of collaboration and integration among different data silos emerges again. This issue is attributed to both technical and social reasons, such as siloed governance architectures that historically made domains management independent, while collaboration issues arise from deficient participation procedures or inadequate methods to bring together various stakeholders in constructing the digital twin. Challenges identified as Ownership, Trustworthiness, and Participation can be somewhat attributed to collaboration since ownership relates to the problem of sharing data from different sources (as citizens themselves), which, in turn, cannot disregard reliable security protocols and the inclusion of underrepresented groups in such projects. The article concludes by presenting the results of a questionnaire aimed at assessing the severity with which technical and non-technical challenges are perceived by an expert audience (unfortunately, the expert's disciplinary affiliation is not made explicit). The vast majority consider the lack of practical value (e.g. business model) as the primary non-technical challenge, while interoperability (e.g. lack of semantic integration among data) is perceived as the most challenging from a technical perspective.

2.4 Some Notes

The meta-literature reviews show various areas of overlap, also citing the same references. It should be noted how from the fist article (2021) to the last (2023) the goal of complete and all-encompassing mirroring (despite reporting the contrary opinion made in a few articles), and analogies like the one between the twin modeling of a city and twin modeling in the fields of aerospace and manufacturing [13], are always present, but on a more cautious tone. The city is a complex and constantly changing ecosystem [15], and its modeling is perhaps more effective, or at least at the moment achievable, when compartmentalized rather than comprehensively integrated. Furthermore, the simulator function is linked to that of decision-making support, but also practices of data sharing and participatory co-construction of models are mentioned. With respect to these topics, it is worth reporting two case studies that all three literature reviews refer to in sections where social and participatory issues are discussed (one case is cited by all three articles, and the other by two).

3 Two Cases

A research that focus on the development of decision-making processes, with DUT working to present possible alternatives to decision-making groups, is about the Herrenberg's DUT [16–18]. The authors present an experiment (participated by various stakeholders) around a prototype of DUT, noting that a classic criticism of this tool is the reductionism of the models it implements: for example, it remains challenging to represent the socioeconomic variables that animate a city. The most highlighted result of the experiment is that was able to effectively communicate in an understandable way to the stakeholders the outcomes of a planning choice through its visualization in the virtual model. This quality would be crucial to enhance communications between citizens and administrations; citizens would be able to account for their expectations, and administrations would explain their decisions more intuitively. Another point of interest is that the Herrenberg's DUT leveraged empirical data provided by the citizens through a process of Volunteered Geographic Information, and pertain to citizens' daily routes, enriched with qualitative notes and evaluations, responding to the developers need to integrate aspects of social life, which are often elusive. The originality of the Herrenberg's DUT revolves around the aim to expand the knowledge base in the context of governance actions: there is an explicit reference to a broad assembly, made of experts but also laypeople. However, the articles are ambiguous about whether this knowledge base is intended to articulate the models and functions of the DUT or is primarily addressed to reach a consensus on specific proposals.

The second case is proposed by Nochta, Wan, Schooling, Parlikad [19], who, not so differently from many STS scholars, refer to the socio-technical term right from the title. The case is not precisely a DUT, but rather a City-scale Digital Model (CDM), a slightly different city model aiming to integrate various models through a strategy that combines the urban governance plan (considered the "social side") with the technical plan consisting of data and modeling. The authors argue that realizing the benefits of digital twins for cities is not automatic, emphasizing the need for interdisciplinary insights and participative processes. They suggest involving prospective users, city planners, managers, residents, and workers, along with researchers and technology suppliers. This collaborative approach aims to shape the evolving concept of CDTs, ensuring meaningful contributions to policy and practice and enhancing the likelihood of successful implementation. The authors advocate for an interdisciplinary perspective to move beyond the current technology hype associated with digital twins. The conventional definition of digital twins as mere replicas of physical systems is deemed simplistic and flawed, as the authors argue that digital twins, particularly in the context of cities or the built environment, should be viewed as an intricate interplay among the digital, physical, and social realms, introducing complexities in applying the digital twin concept to the built environment. Still, the efficacy of CDTs in decision-making hinges on the successful translation of high-level policy goals into practical problems that the model can address. However, this translation necessitates a participatory approach, incorporating in-depth local knowledge and preferences to enhance utilization in city planning and management.

4 A Theoretical Evaluation

A few topics encountered in the meta-literature review are now looked under the epistemological-political angle reported at the beginning of the contribution.

The use of a model as a tool for communicating knowledge about the future is ultimately not different from its historical applications. Even during the Renaissance, renowned architects engaged in the art of modeling with their clients: «there is less left undecided, less that the architect needs to or can alter during construction…Fully detailed models also provide greater control for the client who is better able to assess and understand the whole and the detail» [20]. The aim is to resolve indecision and uncertainty: the future is known in a complete and shared manner by the involved parties (client and architect, in this case). However, as mentioned earlier, various social practices can correspond to equally diverse technoscientific practices: do models and simulations retain their status when, as seen in the two DUT case studies mentioned, there appears to be an exchange of information and co-production involved? Is this co-production limited to making aspects of that future more understandable to stakeholders? Is the participatory approach, reconfiguring social relation in order to gain a broader knowledge base, a matter of knowing the future or producing it?

The implications of these questions for DUTs' research practices are made clear by the sociologist of science Karin Knorr-Cetina [21]. The tradition that extends from scale models to simulations put social actors on a stage (the simulation), requiring them to perform everyday life competently and behave in simulated conditions faithful to real-time daily practices (that means: how many parameters can we add to make it "as real as possible"). This virtual laboratory indeed faces criticism for being conducted in inevitably reductive conditions, potentially yielding non-generalizable results. The careful design of these simulations becomes then crucial to approximate the experience they aim to simulate, aligning with their intended purposes. To address this challenge, those working in simulations develop what Knorr-Cetina refers to as "technologies of correspondence". However, correspondences in the cases reported in the literature appear to be more sought through social reconfigurations external to the simulation theater, such as real participatory processes in which different stakeholders organize themselves (or are organized) to assume different roles. And indeed there is a distinction between model/simulation and experiment. Herbert Simon already introduced an ontological difference [22]: while simulation reproduces only the relationships of one system in another system it aims to replicate, an experiment is constituted of the same material as the phenomenon it studies, isolating parts and observing their behavior under different conditions. In the DUT case, which by definition interacts (or should interact) in an information exchange with the physical city it aspires to model, but also with matter of social order, we are likely dealing with a hybrid between simulation and experiment. If the DUT involves aspects related to experimentation, prediction is not solely based on the ability to construct correspondences but also on actively intervening in phenomena, regardless of the model used [23]. The literature reviewed does not seem to account for this deviation in the techno-scientific practices underlying the DUT, and it does not attempt to view the DUT as an experimental apparatus - with its own political and social consequences - rather than a scenario simulator.

Regarding the ability to provide evidence, even the most socio-technical cases reported in the meta-literature still aim at an evidence available for policy-making. But, as written above, is this solely about evidence, or does it also involve the capacity to incorporate more indeterminate factors? Nochta et al. express in fact concern that the complexity to be represented deepens with multiple decision options that are often incompatible or contradictory, each supported by internally coherent evidence derived from different modeling efforts, and that these models may be developed in sectoral silos or cater to different governments with distinct political leadership and agendas, contributing to the intricate landscape of decision-making in urban contexts.

In the theoretical framework of PNS, the notion of "extended facts" has been put forth to denote a broader understanding of scientific facts that goes beyond mere objective observation or measurement. Extended facts reflect the awareness that science, especially when dealing with complex issues and social controversies, is inherently tied to different values, perspectives, and contexts. This implies that the production and interpretation of scientific facts can be influenced by non-scientific considerations, such as ethical, political, and social aspects. In the context of PNS, there is an emphasis on the need to involve a wider range of perspectives and to consider the plurality of values at play, even in scientific knowledge production. The two DUTs cases presented advance a similar proposal in their own way, but maintaining alongside the participatory engagement of different perspectives a rather traditional conceptual framework of the scientific output (the model to make the understanding of future scenarios more efficient).

These two sides shouldn't be conceptualized and developed separately, as underlined with the distinction between simulations and experiments. Technoscientific knowledge production involves a corresponding reflection on knowledge production in broader and different social arenas than the laboratorial one, with various implications. If the city is composed of measurable entities for which evidence can be approximated, it is equally made up of much more indeterminable factors driven by trajectories definable as intentional. The weight given to these factors and therefore to the unpredictable changes these may undergo, is directly proportional to the level of unpredictability the city as a whole presents. Is it then possible to incorporate intentions and make sense of this unpredictability? Would it be sufficient to build simulations with agents performing increasingly accurate profiles, along the lines of Big Data business models? Or would be sufficient to gather participatory practices? Or to design DUTs to function as if they were more an organization than a technological piece? And if so, should this be a public organization? Could we still talk about knowledge production in the form of models and simulations, or the form of experiments? Or something else entirely?

5 Conclusion

To summarize, the analysis of the meta-literature reports issues that we can define as pertaining to political epistemology: the research on DUTs identifies this aspect as a set of problems that the development of these tools must address. Furthermore, a certain continuity between technical and social aspects is highlighted in the meta-literature, especially in the second case study, where semantic integration among different databases and the trade-off between autonomy and interdependence among governance entities are presented as inseparable issues. What seems to be missing is just as much awareness in considering this area of issues as in need of specific theoretical and disciplinary tools. As we hope to have suggested with this contribution, which concludes with a series of questions aimed at the development of digital twinning practices, theories relating to the political epistemological panorama can play not only a critical but also a constructive role in DUTs research.

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The Italian Way of Urban Regeneration: Where Digitalisation is not a Valid and Fruitful 'Option'

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Abstract. Contemporary cities are facing a challenging shift towards digitalisation, also using artificial intelligence as an important device to provide and elaborate information. Nevertheless, urban planning issues still face limitations concerning this innovative and current topic, with specific reference to decision-making processes. The paper shows the limitations within the Italian context, emphasising the opportunities derived from some structural constraints.

Through a brief overview of the latest Italian problems in digitalisation and technology matters, the paper aims to describe the importance of 'humans' and 'relationships' as un-transferrable elements crucial for successful regeneration cases. The Italian case study is an example of how digital actions are not a priority in decision-making processes, especially with regard to the regeneration of public assets. The paper highlights the importance of governance, social norms and institutions as the main background of decision-making processes, considering digitalisation and other advanced technologies as a potential tool, but not as the solution.

Keywords: Third Sector Organisation · urban regeneration processes · digitalisation

1 Smart Cities, Digitalisation and the Italian Context: A Counter-Trend

The role of digitalisation and artificial intelligence in our contemporary cities is undoubtedly crucial. There is a long-standing debate about 'smart cities' and the importance that new technologies, information and data, and digitalisation have in developing integrated strategies and more sustainable cities [1–3]. Throughout the years, the idea of a 'smart city' and the technologies related to its development have changed. Nevertheless, there is a common idea that 'smart city', and its digital and technological devices might help planners and public authorities achieve more effective and robust performances within the different public urban spheres [3, 4]. More recently, individuals' behaviour and their generative data have been used to understand urban phenomena, introducing the twofold role of individuals as data providers and as decision-makers [5–7]. Furthermore, it has to be considered that together with this incremental interest in information and technologies, the role of social media and communication has increasingly become crucial in urban planning research ([8]; with specific reference to vacant land, see [9]).

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What is crucial is the effective role that digitalisation, technologies, and artificial intelligence might have in highly complex phenomena, such as regeneration processes. These experiences highlight different uncertainties and ambiguities, directly influencing process performance. In particular, the institutional frameworks vary from one case to another, and the solutions *one fits all* are not likely to be experimented. Furthermore, some elements are not tangible (such as the socio-economic and socio-spatial issues and conditions; in this regard, see [10]) as they are context-driven.

The idea of creating more sustainable cities, fostering urban regeneration and adaptive reuse, is extensively shared and supported (considering also the European Agenda for 2030 and 2050, see [11]; compared to [12], which also considers public buildings renovation for at least the 3% of the entire buildings' surface). Second, the use of digitalised information is important to support decision-making (both within the administrative and the civil sphere), to identify potential places for urban regeneration [8], and to create and engage the *community* [9, 13].

Considering the Italian case as the case study, this paper shows the limitations and opportunities that urban regeneration processes face in the light of digitalisation. The role of digitalisation, artificial intelligence and technology might be considered a 'side element' in urban regeneration processes. This is true considering the nature of the processes, and their conflictual dynamics. Moreover, market or non-market perspectives frequently influence the term 'urban regeneration', which mirror the stakeholders' interests [14, 15]. The Italian case of urban regeneration processes is interesting for three main reasons. First, Italy is considered an 'underdeveloped' country concerning digitalisation, positioning itself as the 25th of 27 EU countries [16]. Second, the data available are frequently insufficient to set decision-making arenas (especially if considering public buildings; in this regard, see [17]). Third, the actors and stakeholders interested in urban regeneration processes (e.g. civic actors and Third Sector Organisations) do not consider digitalisation and AI to be crucial elements needed for these processes.

The paper will discuss how technologies and data digitalisation, despite the level of engagement, are not sufficient in situations where complexity is not driven by data but by patterns of behaviour and institutional performances. The paper critically discusses the role digital devices might have in a situation where individuals, public administrations and private sectors are not truly involved in digital transition. It also delves into the potentials and limitations that emerge if coproduction and social interactions are considered. Section 2 discusses the methodology and approach frequently used in urban regeneration processes, taking into account some basic but fundamental elements of urban regeneration processes. Section 3 will describe the Italian context, highlighting the limitations and opportunities that digitalisation and AI might have in these complex processes. Section 4 will underscore how and when digitalisation might improve/or not urban regeneration processes, highlighting the importance of non-digital decision-making as a crucial element of urban planning phenomena.

2 Digitalisation and Patterns of Behaviour

This paper aims to show the controversial relationship between digitalisation and decision-making processes in Italy. The fact of being 'controversial' is twofold. First of all, the Italian situation, compared with the other EU countries, shows how the IT transition is still an ongoing phenomenon (see PNRR – EU Recovery Plan guidelines, actions and funds). This means that there are no specific devices[1] able to support any decision-making processes (especially those related to urban regeneration). Moreover, digitalised information is frequently insufficient to allow a certain degree of intervention and support in decision-making processes (e.g. vacant and abandoned buildings in Italy; in this regard, see [20], considering only 85% of data available). The second reason is related to the very nature of urban regeneration processes, which are considered highly complex [21]. In this regard, the complexity is not only related to the implementation of devices (method) but also to the governance and institutional performance (policy). Moreover, adopting a 'collective action problem' approach to urban regeneration implies that the solutions are influenced by governance structure [18, 22]. In general, considering urban regeneration processes and the institutional background conditions enabling robust performances is crucial, and the role of digitalisation and information could, in specific instances, decrease uncertainty levels [7, 23].

This complexity will be discussed, highlighting how research focuses attention on 'some' specific elements of urban regeneration (e.g. stakeholders; civic engagement; norms and legal framework; digitalisation and information; in this regard, see [24, 25]), whilst dismissing the role of the process *per se*, which is frequently the element that might contribute to the success of a regeneration project [21]. In this regard, the paper adopts a new institutional approach to underscore the limits of digitalisation in practice.

3 The Italian Digital Leftovers Between Practices, Technologies and Innovation

As already mentioned, the Italian situation regarding digitalisation and IT transition is quite problematic. The question of digitalisation is crucial for different reasons. In particular, it is possible to distinguish three main limitations within the Italian context: (i) the Italian general context; (ii) the object in question; and (iii) the actors involved.

The first limitation is related to the structural constraints [26] that Italy is facing concerning digitalisation and the use of technology as a device to improve services and information provision, as well as a tool for enhancing individuals' well-being [16]. The second element of limitation is related to the object that this research will focus on. The digital information and the limits that the public - and, more generally, urban planning - has to deal with are related to decision-making processes in uncertain conditions [27]. In general, data about 'objects needing decisions' are frequently generic: it is the case, for example, of unused publicly owned land and buildings. Third, digitalisation and the use of technologies for decision-making are important for the actors in charge of 'making decisions' [27]. Considering the Third Sector Organisations in Italy, and more generally the 'civic actors', the limits in practices are presented and discussed, especially in regeneration processes.

[1] One recent methods used for decision-making, is experimented in Germany within the public sector. It used a Multi-Level Governance approach combined with digitalisation and collection of information "to design highly prioritised public services" [18, p. 250]. Another recent methods is XR (External Reality) where individuals could provide and visualise specific scenarios (in this regard, see [19]).

These three limitations highlight the challenging context where regeneration processes are happening. In doing so, the complexity of these limitations shows a panorama where uncertainty and ambiguities are an intrinsic part of 'decision-making' in Italy. The aim is to present the limits and acknowledge them in terms of digitalisation, with an insight into digital activities, smart regeneration, and patterns of behaviour. This element is crucial to understand the essential role of information, in relation to 'human' and non-digital actions.

3.1 The Italian Digital Illiteracy vs Public Administrations Adaptation

One of the main problems of digitalisation in Italy is the lack of knowledge and 'digital literacy'. This term means a condition where the individuals are acknowledged and capable of using and mastering a set of skills (digital skills) that are needed in the 21st Century to use digital devices able to enhance and support their life achievements (on 'digital literacy' see [28]; compared to [29]).

Italy, in fact, presents quite structural and traditional problems related to digitalisation, and some of them are linked explicitly with 'digital illiteracy'. Considering the latest DESI report [16],[2] Italy positions itself 18th of 27 European countries based on the overall level of digitalisation and technologies. Furthermore, if it considered the EU Recovery Plan *PNRR* (*Piano Nazionale per la Ripresa e la Resilienza*), the amount of EU investments signed for Italy is the highest compared to the others: one-fourth (25.1%) of the entire investment is devoted to the IT transition in general [16].[3] This datum is quite self-evident and highlights the difficulties organisations and individuals face regarding digitalisation. Two DESI indicators are significantly below the average: human capital and public digital services.

Regarding the 'human capital', Italy stands 25th of the 27 European countries. This is also confirmed by the Istat data about digitalisation, which highlights that only 46% of the population (between 16 and 74 y.o) has basic digital knowledge [30]. The gap is more evident if more advanced digital skills are considered, highlighting that it is only 23% [16, 30]. From an individual perspective, Istat (2023) analyses the 'digital individual skills', highlighting another important and crucial gap, which is territorial: based on the EU standard for 2030, Northern regions should gain 3% each year, whilst Southern ones should gain 5% [30]. Moreover, if it is considered the Censis report (2023), digitalisation and new technologies, in general, are seen as an opportunity by 67.4% of the population, which means that still 32.6% either do not have a specific idea in this regard or do consider digitalisation as a hazard. Another important data to consider is the use of digitalisation by Italian small and medium enterprises (SMEs) [31]. Also, in this case, Istat highlights that over 57% of them have externalised the design and the management of ICT activities [30].

[2] DESI is the acronym of Digital Economy and Society Index. It is an annual report that EU Commission does to trace the European countries development in digitalisation. The DESI analysis includes four different indicators: (i) human capital; (ii) connectivity; (iii) integration of digital technology; and (iv) digital public services.

[3] Considering that the overall EU investment is 191.5 billion euros, the digital and technologic transition funds for Italy are around 48 billion euros.

Considering the 'digital public services' indicators, Italy is the 18th of 27 EU countries. In this case, the EU average is 64%, whilst the Italian one is around 36%. This *datum* is related to the digitalisation of public services (e.g. e-government; e-health systems). However, a recent report [32] analysing the digital development of Italian municipalities, highlights that 76% of municipalities in the analysis[4] are achieving a 'good' level of digitalisation[5] overall. What emerges is the role of medium-sized cities, which are gaining importance, as around 51% of municipalities are achieving 'high' or 'medium-high' digitalisation standards. The same is true when considering the aforementioned territorial fragmentation, where Southern cities are gradually narrowing the gap with Northern ones: Southern municipalities in the higher benchmark are 37%.

The digitalisation context in Italy is very challenging. On the one hand, the sceptical approach towards digitalisation and technologies from individuals seems to balance the progressive, but slow, digitalisation of public administrations. On the other hand, the role of ICT is crucial in defining decision-making processes, which means that uncertainty, individual behaviour and public administration approach are at stake.

3.2 Vacant Lands and Buildings for Regeneration Processes: Data vs Policies

This paper discusses the role of digitalisation in decision-making processes, with specific reference to regeneration processes. The role of these experiences has been at the centre of recent EU Resolutions (e.g. Agenda 2050; Habitat III report). In this panorama, urban regeneration processes have increased their impact and importance on local and national urban agendas. This phenomenon happens also in Italy, where it is largely developing across municipalities. In general, regeneration processes meet unused buildings and lands that have been abandoned due to the after-crisis real estate downturn.

What is crucial is the limitation of data and public inertia, which resulted in analysing only a few portions of a chosen phenomenon (in this regard, see [17]). For instance, considering the case of unused publicly owned buildings and land in Italy, the latest report available was published in 2021 and refers to 2018's data [20].[6] Furthermore, this report collects a set of different information about public portfolios,[7] which are not freely available, and that refers to the 85% of municipalities that decide spontaneously to fill the list of their local properties. All these data are supposed to be public, but it rarely is. Overall, this report highlights that part of this public portfolio is unused, neither directly nor indirectly,[8] leading to a waste of public resources. In the logic of regeneration, these buildings (for 'land' is different as they could be wood or agricultural

[4] This report analyses only the municipalities that are provincial capitals (110 municipalities).

[5] The higher level of indicator is 'high, followed by 'medium-high', 'medium-low' and 'low' (for further information about indicators, see Table 5.1 of [32, p. 35].

[6] The last census is ongoing (2023): https://upel.va.it/2023/05/04/patrimonio-della-pa-al-via-la-rilevazione-dei-dati-dei-beni-immobili-pubblici-triennio-2020-2021-2022/ (last access 12th December 2023).

[7] There are territorial agencies and other non-territorial agencies that own a specific portfolio. For more information about the different categories, see [20, p. 9].

[8] If the asset is used directly, it means that the public administration is effectively using the asset for the specific institutioianl purposes of the agency. If the asset is not used directly, then it might be: (i) used by another public agency; (ii) used by the private sector; (iii) ongoing maintenance.

lands) have an appropriate potential. They cover 7% of the total of the public portfolio, with an estimated value of around 13 billion euros [20]. If it is considered another – and more recent – report designed by *Agenzia del Demanio*[9] (2023), the amount of publicly owned assets (buildings and lands) is more than forty-three thousand (compared with the MEF report, which considers more than 2.7 million assets).[10] However, in this case, the report does not focus on the number of units that are left unused [33], and the online platform for leases and privatisation sets a shortlist for those with an open call.[11]

This lack of data emphasises two main risks in decision-making processes. First of all, the out-of-dated (or missing) data could negatively affect the outcome of the decision and the process itself. Second, the ambiguity of the *datum* cannot be double-checked, as there is not a fully available list of these assets, and if they are, they are not comprehensive.[12] For urban regeneration processes, not knowing some basic elements of buildings or lands that are publicly owned is a risk: on the one hand, procedures and regulations might be very different (e.g. heritage and historical building; *Demanio*'s land; public building or land serving public interests); on the other, not knowing *a priori* the 'available' public portfolio, which could be subjected to urban regeneration processes, is a citizenship issue. If the magnitude of the phenomenon of unused public assets and their basic features and information is not precise, the ambitious digitalisation project seems to be effective only in theory. This situation of uncertainty happens because no (or not precise) key elements might be considered in decision-making processes.

3.3 Third Sector Organisations: Digitalisation vs Innovation

After discussing the context where regeneration processes are taking place and the kind of objects they refer to, it is important to discuss and analyse one of the main actors involved in these kinds of experiences. Generally, the stakeholders engaged in regeneration processes are the so-called 'civic actors' [21], but there is insufficient data to analyse them properly. Some of the civic actors are not formalised groups [34], which means that information about activities, experiences and social engagement might remain uncertain. Those informal groups understand the role of digitalisation in institutionalising and legitimising their activities (in this regard, see [35]). For this reason, the analysis will be devoted only to one component of this 'umbrella term': the Third Sector Organisations.

The latest report outlined by Istat [36] highlights some basic features of this sector, which is continuously increasing, with an exponential boost (+46%) between 2001 and 2016, due to the economic crisis and the progressive public sector withdrawal. Since 2016, Third Sector Organisations have increased by around 5%, reaching 363,499

9 *Agenzia del Demanio* manages State properies, with specific reference to 'non-mobile' assets, such as heritage buildings, public goods (e.g. beaches, rivers, infrastructures), and other typology of 'mobile' assets (referred to article no. 822 of Italian Civil Code).

10 It has to be noted that *Ministero dell'Economia e delle Finanze* (MEF) report takes into account *Agenzia del Demanio*'s assets, which are around 94 thousands (building units and lands).

11 To check the privatisation or the leases of public portfolio: https://venditaimmobili.agenziademanio.it/AsteDemanio/sito.php (last access 12th December 2023).

12 For instance the *Ministero dell'Economia e delle Finanze* report [20] is collecting different data from the latest report by *Agenzia del Demanio*. This creates ambiguities both in terms of property and in terms of information.

organisations in 2021. These non-profit organisations are considered an important sector between the public and the private ones, providing services that frequently are related to welfare and care. Some of them are engaged in the regeneration processes of unused public buildings, and their ability to be part of the process is crucial [21, 34, 36]. This report shows that digitalisation and technologies are not considered a priority for these organisations: 20.5% are non-digitalised and do not use digital devices (e.g. internet connection, mobile apps, cloud). There are two reasons: one depends on their very nature of being non-profit, and the other is related to digital illiteracy in general (see Sect. 3.1). First, the Istat report highlights that 26.4% of non-digitalised non-profit organisations do not have enough resources to invest in digitalisation activities; second, 15.7% combine this lack of digitalisation with the general phenomenon of digital illiteracy [36]. Nevertheless, this report shows that digitalisation and the use of technologies within these organisations are not crucial elements. More specifically, what is essential for non-profit organisations, especially if they are willing to provide facilities and services for social purposes, is networking and relationships. In particular, 89.3% of non-profit organisations have significant relationships with other stakeholders.[13] Particularly important for urban regeneration processes are those with Regions and local authorities (36.1%) and those with other State offices (12.2%). Unfortunately, it is not possible to derive the motivation with these connections, but it is possible to assume that a part of them is because the unused assets are publicly owned.

4 The Non-Human and Digital Devices as Support for Human Practices

The Italian case emphasises two different sides of the digitalisation phenomenon. On the one hand, it shows all the limitations present in the Italian context, related to different kinds of constraints; on the other hand, for each issue presented, there is the reverse side, highlighting the positive aspect of not being advanced in digitalisation.

It is clear that, despite digital illiteracy, lack of definite data and scarce use of digital devices, some positive elements and opportunities might arise. First, digital illiteracy is still a problem in Italy, but in the era of technology and digitalisation, public administrations are incentivising citizens' use of digital devices. This condition might not influence all individuals' behaviour, but it could highlight the potential positive outcome of 'being online'. Second, urban regeneration processes take place in public assets where the only relevant information is that they are abandoned. It is undoubtedly necessary to have a precise list of public portfolios [37], but the main goal is not directly related to decision-making activities but to management and economic activities [38]. For the same reason, the third limitation emphasises the role of stakeholders and their relationships to achieve agreements and stable networks rather than being 'digital'. Moreover, being non-profit means they use their resources and capabilities to engage citizens in urban regeneration activities and raise interest in the phenomenon.

[13] Respectively: regions and local authorities, 36.1%; other non-profit organisations, 19.9%; schools, universities and other research centres, 15.8%; religious organisations, 12.2%; State offices, 10.9% [36, p. 14].

Although the paper does not delve into urban regeneration processes, contemporary literature has extensively discussed this phenomenon [17, 21, 39, 40], specifically related to civic actors and their active participation and engagement in these processes and projects. It is clear that, despite the lack of digitalisation and specific devices for decision-making processes, the experiences of the revitalisation of unused buildings and land continuously rise. Local authorities and regulations also support urban regeneration processes, allowing civic actors to temporarily use those spaces for collective interests. This means that even if the level of the different limitations occurring in the Italian system has been low, the outcome of a 'decision' could not be deeply influenced by the 'non-human activities and information' but, on the contrary, it relies on social dynamics and patterns of interactions that are complex and difficult to systematise and shape. For example, if information about public assets is digitalised and precise, it will be not sufficient to set and design effective decision-making arenas [7]; on the contrary, working on regulations might help lower uncertainty and enhance practices [21, 27].

5 Conclusions

The role of digitalisation and technologies in urban regeneration processes is not considered a relevant or powerful device on which decision-making processes might rely. This does not mean that they are unnecessary, but they are not considered as such because there are other more important factors to examine while discussing urban regeneration processes. In general, it has to be noted that regeneration processes and policies are frequently influenced by contextual circumstances and institutional patterns, which are – for their nature – either excluded from the digital domain or too sensitive to be taken into account in a 'model'. This mismatch between digitalisation and relationships leads to create institutional performances that are more related to social interactions, able to lower the level of uncertainty and setting the specific context-driven conditions for decision-making processes. This does not mean that digitalisation in decision-making is not fruitful but, rather this discussion pinpoints the important role of individuals and their interactions in setting more effective decision-making processes.

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Machine Learning in Urban Decision-Making: Potential, Challenges, and Experiences

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Abstract. In this review paper, the authors highlight Machine Learning (ML) applications to assess their usefulness quantitatively and qualitatively in urban planning decision-making processes. The ML algorithms and broader Artificial Intelligence (AI) seem to have a more comprehensive application range and the ability to acquire information and knowledge even from spurious datasets. The current research aims to briefly define the emergent field of the most used algorithms of machine learning in urban planning and their usage in decision-making as well as analyzing their potentials and limitations. They have been done by presenting some classifications based on a literature review and finally providing a qualitative assessment of the described algorithms. This assessment puts into evidence the advantages and disadvantages of using the present algorithms in Urban planning decision-making usefulness.

Keywords: Machine learning · Urban Decision-making · Review paper · Algorithms

1 Introduction

Each day, urban agents encounter myriad choices that require careful consideration and analysis to arrive at sound decisions [1]. In this regard, digitalization could play an important role in the decision-making process. Digitalization is becoming increasingly popular in our daily lives, propelled by advancing computational capabilities and the advent of efficient algorithmic processes that streamline data mining [2]. The decision-making process, which relies on selecting algorithms or models, involves considering available procedures or conditions and choosing the most suitable one to solve specific problems [3].

Machine learning (ML) is a decision-making tool widely used in many fields that require the building of knowledge from big amounts of data or inhomogeneous ones [4]. Aligned with this perspective, ML, situated at the crossroads of informatics and statistics, presents an exciting opportunity for fostering evidence-based decisions. This initiative addresses the current void in technological tools and instruments tailored for spatiotemporal needs [5, 6]. The authors intend to qualitatively evaluate how applying ML techniques facilitates the automation of decision-making and accelerates the optimization procedures in different domains of urban transformations. Moreover, the

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contribution demonstrates that ML empowers urban planners to remove laborious tasks and enables them to predict optimal scenarios for multiple urban policies in a direct way [7]. This research by using a systematic literature review tried to summarize the most important Machine Learning algorithms that can be used in different urban planning decision-making subjects to know which of them have given more reliable results based on each subject as well as introducing their limitations and potentials.

2 Artificial Intelligence and Machine Learning

Artificial Intelligence (AI) encompasses the advancement of computer systems capable of executing tasks associated with human intelligence. Artificial Intelligence (AI), incorporating ML and neural networks (NN), has been a subject of exploration in various scientific domains such as healthcare, transportation, finance, engineering, and education [8, 9]. These tasks include speech recognition, visual perception, and natural language processing. Indeed, AI systems exhibit diversity, expanding from rule-based to machine-learning-based approaches.

As previously mentioned, ML is identified as a subfield of artificial intelligence [5] that encompasses the creation of algorithms and models designed to learn from data, enabling them to formulate predictions or decisions without the need for explicit programming [10]. In other words, ML can be explained as a discipline concerned with implementing computer software that can learn autonomously, and it could be helpful in reasoning, planning, or problem-solving [9]. Also, it can be defined as an iterative process involving the generalization of data through successive stages, including data collection, comparison, categorization, feedback, and self-tuning. The ML taxonomy generally includes three main categories: supervised learning, unsupervised learning, and reinforcement learning [5–11]. Additionally, a non-parametric ML technique designed for capturing and modeling intricate behaviors and patterns is often assimilated to the human nervous system. This approach can recognize and categorize patterns through training or learning processes. Notably, it excels in handling the uncertainties associated with spatial data and adeptly addresses non-linear statistical scenarios [12].

Supervised learning methods build their classification or prediction models by establishing a learned mapping through the observation of input parameters. Unsupervised learning methods focus on identifying clusters within the data, with 'k' denoting the number of clusters generated by the algorithm. Finally, Reinforcement learning is a distinct type of ML that entails an agent interacting with an environment to acquire the knowledge of optimal behavior within that particular environment [5].

3 Reviewing Machine Learning Use Cases in Urban Decision-Making (Methodology and Design as Well as Literature)

A systematic literature review has been used to conduct the research. Different databases(Scopus, Science Direct, and Google Scholar) and a variety of keywords (Mostly: ML+Urban planning, ML+Urban decision making, ML+risk management, ML + diaster management, ML+urban Mobility, ML+Urban policy, ML+Land use, ML+Urban development, ML+Climate change) in the title and abstracts of the documents has been analyzed for identification of the papers. In the next step some of the articles were chosen after reading their abstracts and in the next step some of them were removed after skimming the text body for which they were not directly related to urban planning issues, and by reading the eligible remaining articles a few of them have been selected. Then based on the methodology and the main subjects, for those with exact methods and subjects a few of them have been chosen for more analysis.

After clarifying the framework characterizing the implementation of ML, the authors proceed by collecting and assessing experiences concerning the use of ML applied to decision-making processes in the urban planning domain, which can be used for Classification and Regression, Clustering, and Predictive Modeling [13]. Therefore, the most recent references have been considered and reported in the following Table 1. The latter refers to different fields of action, including the spheres of urban planning and development, transportation management, resource allocation, and environmental sustainability.

Motta, etc. [14] analyze the application of ML to predict floods in urban areas. In particular, diverse machine-learning algorithms that can be employed to learn a given kind of model are discussed. The most performant algorithm is represented by the Random Forest (RF). RF is well-versed in navigating through high-dimensional data and skillful at capturing complex interactions among variables; it basically combines the outcomes of numerous decision tree structures to produce a unified result. Its widespread adoption can be attributed to its user-friendly interface and versatility, allowing it to address both classification and regression challenges. However, its robustness to noise and outliers carries a potential drawback – the computational expenses may increase, leading to a risk of overfitting when the decision's tree count is excessively high.

Another algorithm examined is the K-Nearest Neighbors (KNN), an algorithm utilized in pattern recognition to classify objects by considering the characteristics of neighboring objects in relation to the one being examined. However, it comes with its intricacies, being responsive to the selection of a distance metric and the quantity of neighbors for classification. Moreover, its computational requirements may increase for large datasets. The Multi-layer Perceptron (MLP), a non-linear, feedforward artificial neural network, is adept at deciphering intricate non-linear relationships within high-dimensional data. However, its effectiveness relies on meticulous hyperparameter selection, and there is a potential for overfitting if the network architecture becomes too complex. The mentioned authors also discuss the Logistic Regression (LR) algorithm, which is greatly appreciated for its simplicity, interpretability, and effectiveness with high-dimensional data. While it provides valuable insights into variable importance, LR's limitation lies in assuming a linear relationship between predictors and the response variable. This assumption may result in shortcomings when attempting to capture complex non-linear relationships.

The Support Vector Machine (SVM) is a classifier based on a Gaussian kernel. The latter excels in navigating non-linear decision boundaries and demonstrates robustness against noise and outliers. Despite its computational efficiency in managing high-dimensional data, its sensitivity to kernel function and regularization parameter choice should be carefully considered. Finally, still considering the urban flooding prediction,

Table 1. Examples of Machine Learning algorithms applied to the Urban Planning domain.

Domain	Algorithm	Authors
Flood prediction in urban areas	Random Forest (RF) K-Nearest Neighbors (KNN) Multi-Layer Perceptron (MLP) Logistic Regression (LR) Support Vector Machine (SVM) Gaussian Naïve-Bayes (NB)	[14, 15]
Urban mobility policy	Decision tree (DT) Random forest (RF) Linear support-vector regression (LSVR) Gradient-boosting regressor (GBR)	[7]
Extracting greenery from street view images (image segmentation)	SegNet algorithm	[16]
Urban growth, Prediction of future urban boundaries for expansion and urban agglomerations	Time Delay Neural Network (TDNN) Artificial Neural Networks (ANN)	[12–17]
Urban Vehicular Ad Hoc Networks	Machine Learning-assisted Route Selection (MARS)	[11]
Qualities of the urban environment	Convolutional Neural Networks (CNNs)	[10]
Land use planning	Logistic Regression Support Vector Machines (SVM) Random Forest (RF) Neural Networks (NNs) Markov Random Field (MRF) Agent-Based Modeling (ABM) Generative Adversarial Networks (GANs)	[18, 19]

the Gaussian Naïve-Bayes (NB), a non-linear Bayesian classifier, is also evaluated. It stands out for its simplicity, efficiency with high-dimensional data, and probabilistic prediction capabilities. However, it depends on the assumption of predictor independence, which might not precisely catch the variables' level of complexity.

Regarding the same domain, [15] state the efficiency of machine-learning methods in urban flood-risk assessments, particularly when applied in areas with limited data for traditional engineering modeling. Key indicators influencing flood hazard include distance to river, urban drainage density, and proximity to vulnerable urban areas.

Shulajkovska, etc. [7], by putting the attention on the urban mobility policy domain and highlighting the use of some specific algorithms. Among these, they also described the previously introduced Random Forest, emphasizing its learning approach that enables the building of multiple decision trees during the training phase. Moreover, they describe the Decision Tree (DT) model, which is structured as a tree showing a set of decisions and the possible effects that may derive from them. The Linear support-vector regression (LSVR), a regression-focused supervised learning algorithm, constitutes a variant of the Support Vector Machine (SVM) algorithm designed to address regression tasks. An additional technique is the Gradient-Boosting Regressor (GBR), which combines numerous weak learners, most of the time decision trees, to build a resilient learner with improved predictive capabilities.

In the research of Tang, etc. [16] examining the use of SegNet algorithm as an effective tool for extracting relevant spatial features related to greenery has been analyzed. Through image segmentation, this algorithm can positively support the analysis of human-scale factors that are fundamental to address environmental assessment.

The estimation of urban growth to predict future urban boundaries and agglomeration is supported by the use of a non-parametric ML technique, i.e., the Artificial Neural Network, as evidenced by [12–17]. The tool's potentialities are interesting. The latter is skilled in quantifying and modeling complex behaviors and patterns. Moreover, the model demonstrates its proficiency in recognizing and categorizing patterns through training or learning processes. It is equipped to effectively manage uncertainties inherent in spatial data and address non-linear statistical cases. The ANN is a flexible model that can handle many data types, including map images and text data. The model adaptability feature makes it particularly suitable for examining complex urban phenomena and identifying patterns in urban evolution. Among the ANNs, [17] used the Time Delay Neural Network (TDNN), which relies on equal time intervals of urban growth. This ML framework allows monitoring and forecasting of the trajectory of urban spatial expansion. Therefore, it facilitates the formulation of policies aimed at safeguarding ecological and agricultural lands while optimizing and guiding the course of urban growth employ ML tools to develop a routing information system has been done by Lai, etc. [11]. The latter is able to anticipate the trajectory of vehicles and subsequently select optimal routing paths. Moreover, it supports the collection of more exhaustive and live traffic information.

Another work from [10] describes the development and testing of three ML models to assess, through automatic procedures, physical qualities in the urban environment applied to a larger scale. Particularly, the study is centered on the visual quality of architectural facades and the visual continuity of street walls. Convolutional Neural Networks (CNNs) have been applied, which enable the extraction of more accurate results linked to real experiences in the urban environment. However, the algorithm's performance could be reduced due to the entirety of visual cues; this lack opens the discussion on how to improve the complex visual factors concerning deep learning.

The study by [19] suggests that the most effective methods for classifying land uses include Support Vector Machines (SVM), Random Forests (RF), and deep learning techniques such as Convolutional Neural Networks (CNNs).

Another approach discussed by [18] is the use of Markov Random Fields (MRF), which proves valuable in urban land use planning, image segmentation, texture analysis, edge detection, and picture restoration. MRF, being a statistical model grounded in probability theory, adeptly captures dependencies between pixels in a spatial domain, facilitating the representation of spatial-contextual information [18]. Generative Adversarial Networks (GANs) have been employed for urban pattern simulations. The mentioned authors highlight the use of various algorithms in examining urban expansion, land use change, and settlement pattern analysis. These include cellular automata, spatial logistic regression, and agent-based modeling.

In this way, it is possible to have a clear representation of the analysis that has been described before (Table 2) which illustrates the most usage of each algorithm in each urban decision-making topic and their possible benefits and limitations. These positives and limitations could help researchers and planners to choose the best algorithms based on the subject that they are working on.

4 Discussion and Conclusions

When choosing a ML model to be employed for a specific application, it is fundamental to carefully evaluate the inherent limitations and trade-offs associated with each model while also recognizing their potential advantages.

In the context of urban planning, the analyzed ML models can effectively conduct large-scale and automated evaluations of the qualities of the urban environment. Indeed, they provide an alternative to the traditional, expensive, and labor-intensive methods, offering more efficient and cost-effective solutions for measurement and analysis. Valuable knowledge is transferred into the drawing of urban policies to enhance transparency and significantly expedite decision-making processes.

Overall, ML offers urban planners' various benefits:

- Automated decision making: ML methods streamline decision-making processes, accelerating optimization and enabling urban planners to predict optimal scenarios for urban policies, bypassing time-consuming tasks.
- Efficient policy testing: instead of simulating a set of possible scenarios, ML models can be instructed on a subset of pre-simulated scenarios, thus affecting the time and resources required for decision-making while still providing reliable policy suggestions.
- Insights and transparency: ML yields valuable insights into effective urban policies, ensuring transparency and significantly expediting the decision-making process.
- Data analysis and pattern recognition: ML algorithms can examine numerous datasets, identify patterns and trends, and support advanced policy decisions, empowering urban planners to support informed choices concerning the city's future. By harnessing ML, urban planners can improve decision-making efficiency, accuracy, and consistency, leading to more successful and sustainable urban mobility policies [7].

The qualitative analyses of the algorithms that, from the literature review, emerged as most used highlight some diffuse constraints that can limit their use in a comprehensive and aware decision-making process about urban planning:

1. Each of these algorithms must be taught starting from well-known, similar examples. This issue is a clear limitation of the possible application fields in urban planning, considering the complex nature of urban phenomena [20] and the uncertainty level in many urban topics [21]. From a general point of view, many urban problems can have similarities, but the specificity of situationism and local-based analysis highlights some theoretical problems more than practical ones.

Table 2. Assessment of most used algorithms.

Algorithm	Authors	Topic-Applications	Positive elements	Possible limitations
Random Forest (RF)	[14, 15]	Risk prediction (flood prediction, etc.) Land use planning, urban land cover, land values Water quality and water demand	Versatile, user-friendly, and suitable for both classification and regression challenges	Potential risk of overfitting with excessively high decision tree counts
K-Nearest Neighbors (KNN)		Risk prediction (flood prediction, etc.) Land values, land use planning, Urban heat island (UHI)	Effective in pattern recognition, classifying objects based on characteristics of neighboring objects	Sensitive to distance metrics and quantity of neighbors, computational requirements may increase for large datasets
Multi-Layer Perceptron (MLP)	[14, 15]	Risk prediction (flood prediction, etc.)	Adept at deciphering intricate non-linear relationships in high-dimensional data	Requires careful hyperparameter selection to avoid overfitting with complex network architectures
Logistic Regression Support Vector Machine (SVM)		Risk prediction (flood prediction, etc.) Land use planning, urban land cover, land values	Efficient in managing high-dimensional data, robust against noise and outliers	Sensitivity to the choice of kernel function and regularization parameter
Gaussian Naïve-Bayes (NB)		Risk prediction (flood prediction, etc.) Urban function from landscape metrics Land Surface Temperature (LST) Urban Heat Island (UHI) Water demand	Simple and efficient with high-dimensional data, probabilistic prediction capabilities	Depending on the assumption of predictor independence, may not capture variable complexity precisely

(*continued*)

Table 2. (*continued*)

Algorithm	Authors	Topic-Applications	Positive elements	Possible limitations
Decision Tree (DT)	[7]	Urban mobility, environmental issues, urban structures Types, urban land cover, urban growth	Presents decisions and their possible effects in a structured tree format	Prone to overfitting, particularly with deep trees
Linear Support-Vector Regression (LSVR)		Urban mobility	A regression-focused variant of SVM, effective for regression tasks	Sensitivity to Outliers, Limited for Non-linear Relationships, Choice of Kernel (which is challenging in some cases)
Gradient-Boosting Rgressor (GBR)			Combines weak learners to build a resilient learner with improved predictive capabilities	Prone to overfitting Sensitive to hyperparameters computationally expensive
SegNet algorithm	[16]	Image segmentation, Urban growth	Effective for extracting relevant spatial features related to greenery through image segmentation	Complexity and computational cost require large amounts of annotated data Limited robustness to variations
Artificial Neural Networks (ANN)	[12, 17]	Urban growth and Prediction of future urban boundaries	Skilled in quantifying and modeling complex behaviors, proficient in recognizing patterns	Requires careful handling of uncertainties in spatial data and potential overfitting

2. These algorithms can furnish credible possible scenarios for specific topics (such as risk management and urban mobility), so their application is strictly thematic. Most of the urban planning decision-making processes are not related to one single topic, but they are comprehensive and need to represent a synthesis of advantages and inconveniences. For example, mobility topics are usually related to environmental impacts and improvement of security along the road system, as well as a bike network

in cycle paths requires decisions about limiting the use of land for green or other public facilities.

3. Because of the complex nature of urban problems, the decision-making process is not sampleable with heuristic, stochastic, and statistical models. Since ML works mainly with these three models, and its algorithms are educated statistically, the ML tools are devoted to furnishing simplified solutions that the urban planner can consider only as partial scenarios.

Nevertheless, the fast growth of ML and AI tools, and especially the increasing numbers of their applications, promise a continuous improvement of both algorithms' complexity and testing. So, some of the previous theoretical and practical limitations can find positive answers in a limited time. These limitations could be concluded into, Data Quality and Availability, Complexity of Urban Systems, Dynamic Nature of Urban Environments, Interpretability and Explainability, Bias and Fairness, Privacy and Ethical Concerns, Resource Constraints, Human Judgment and Expertise, Long-term Impacts, and Unintended Consequences. In conclusion, we can presume that ML is currently a fantastic accelerator of data finders and organizers as well; additional advances will have to be seen in the area of knowledge construction.

In conclusion, we can assume that ML is also nowadays a great accelerator of data organizers and data finders; regarding knowledge building, it is necessary to wait for further developments.

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The Verification of the Financial Feasibility of a Former School Reuse Intervention in a Small Town in South Italy

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Abstract. Within the current issue related to the redevelopment of educational buildings, in the present research a case study concerning the reuse intervention of a former school is illustrated. By assuming the implementation of a Public Private Partnership procedure, the financial feasibility of the initiative (i.e. from the private investor point of view) is verified through the development of the Discounted Cash Flow Analysis. The paper intends to highlight the relevance of carrying out targeted interventions on this asset typology, in order to define effective strategies of functional reconversion and/or renovation of the existing public properties, due to their attested growing obsolescence state and their needs for greater security and energy efficiency.

Keywords: school buildings · educational facilities · obsolescence · energy retrofit · redevelopment projects · functional reconversion · financial feasibility · DCFA

1 Introduction

The redevelopment and/or functional reconversion of abandoned and/or disused school buildings constitutes an important issue debated in the context of city development policies. The strategies promoted by Europe aim at a significant renovation of the asset towards nearly Zero Energy Buildings (nZEB) standards, starting from a systemic knowledge of the existing stock [1, 2]. In general terms, the educational buildings represent approximately 18% of all non-residential buildings in Europe and more than 50% were built before 1990, of which 60% are in Mediterranean countries [3–5]. The growing obsolescence and deterioration process of this category of infrastructure makes it necessary the definition of actions at different levels capable of increasing their internal accommodation comfort and, at the same time, improving their energy performance [6, 7]. The diagnostic phase of the building maintenance state, energy efficiency and internal/external spaces quality level after many years of use, is essential to develop feasible

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and effective renovation measures [8]. In line with the European Union (EU) Directive 2018/844 [9] and the European Green Deal [10, 11], each EU nation should establish and undertake long-term initiatives to support the recovery of its buildings to those of nZEB by 2050 [12, 13] in order to adapt educational structures to new needs and climate change.

Among the social infrastructure, the educational infrastructure includes facilities hosting early childhood education services, kindergartens, primary and secondary education and higher education institutions. Within the framework of policies to strengthen such infrastructure, there is improvement of the system for the provision of school services and the improvement of buildings in terms of safety, environmental sustainability and innovation, including through the construction of new buildings and/or the demolition and reconstruction of existing buildings [14]. In the Italian territory, the implementation of interventions aimed at transforming the traditional classrooms into innovative ones, as connected and digitally-oriented learning spaces, presumes the creation of flexible and modern spaces as also stated by the National Recovery and Resilience Plan (NRRP) Mission 4 Component 1 Investment 3.2 "School 4.0 - innovative schools, new teaching classrooms and laboratory" which is focused on the acceleration of the digital transition of the Italian school system [15].

In Italy out of a total of 40,133 currently active school buildings, for 7,069 properties the data related to the construction period is unknown, whereas 18,889 buildings (i.e. 47% of the total) were built before 1976 [16, 17]. According to the information reported in the National Register of School Buildings, 23,330 (57.90%) educational facilities are not fit for use, 22,130 (54.92%) do not have the fire prevention certification and 16,681 (41.4%) are currently without static safe verification [18]. The significant need for the upgrading of existing assets is strongly linked to the age of the buildings, the average of which is about 53 years [19], and is confronted by a long period of considerable scarcity of public funding, which has led to the activation of a few extraordinary and ordinary maintenance interventions.

The current urge of launching initiatives to refurbish and retrofit the national asset intends to i) break down the physical architectural barriers (allowing the full use of the spaces for students with motor disabilities), ii) improve the buildings accessibility (in order to allow students with sensory disabilities to utilize the different places), iii) seismically adapt the buildings to achieve the structural safety levels required by the regulations in force, iv) increase the energy efficiency to guarantee safe and sustainable spaces.

2 Aim

In the present research the *ex ante* verification of the financial feasibility of the reuse intervention of a former school building located in a small town of Southern Italy is carried out through the implementation of the Discounted Cash Flow Analysis (DCFA) [20–24]. The publicly owned property is unused for several years and, with the functional reconversion project, will become a multifunctional building for free time entertainment activities and events for the enhancement of the territory. In this sense, the research has a dual objective: the first one is related to the explanation of the central role assumed by Public Private Partnership (PPP) concession operations in the context of urban initiatives for the introduction of new services and infrastructures (currently missing or characterized by a poor quality level). The second aim concerns the implementation of the financial feasibility analysis of the considered intervention of a school building functional reconversion, in order to verify the convenience of the private investor to take part in the PPP initiative. In this way the financial analysis allows the development of the financial plan of the initiative for the private investor.

The sections' articulation of the paper is below described: in Sect. 3 the topic of the redevelopment of the public buildings, which are partly obsolete (around 60% of the total asset) or not always adequate for the needs of the community, establishing cooperation procedures between the public and private sectors is dealt with. In Sect. 4 the case study is illustrated, and the application of the financial analysis is carried out. In Sect. 5 the conclusions are discussed, and further insights are outlined.

3 The Redevelopment of the School Buildings Stock

Within the Italian context, among the governance tools in the field of school buildings, the Legislative Decree No. 65/2017 has broaden the set of initiatives admitted in the national planning by including the projects aimed at the refurbishment, the securing, the anti-seismic adaptation, the energy efficiency and the redevelopment of public properties to be used as "children's poles" for the reception of multiple education and training facilities for children up to 6 years old.

In order to define a new national program of interventions in the field of school buildings for the three-year period 2018–2020 - launched with the Decree of 3 January 2018 - the regions were required to notify to the Ministry of Education the regional intervention plans drawn up on the basis of the requests of the local entities. The next updates for the years 2019 (Ministerial Decree No. 681 of 30 July 2019) and 2020 (Ministerial Decree No. 8 of 7 January 2021) have once again highlighted the public attention paid to the school buildings and the inclusion of initiatives on this asset within the urban development strategies. Among the several funding lines, the Single Fund for school buildings (Fondo Unico per l'Edilizia Scolastica - established by the Legislative Decree No. 179/2012) and its specific section (Legislative Decree No. 124/2019), whose financial resources - equal to € 5 million for 2019 and € 10 million per year from 2020 to 2025 - are intended to finance the urgent and non-deferrable needs for the safety and energy retrofit of public school buildings, including those that emerged following seismic vulnerability verification.

Following the COVID-19 pandemic emergency, the Legislative Decree No. 104/2020 and Legislative Decree No. 34/2020 have been provided in order to support the local entities in urgent school building interventions for the containment of the contagion and the continuity of the learning activities, by allocating € 30 million for 2020.

In the framework of contributions to be used by provinces and municipalities, the 2019 budget law (L. No. 145/2018) has set up the attribution to the provincial institutions of the regions. In addition, for 2019 the assignment to the municipalities of financial resources for investments for the safety of schools, within the overall limit of € 400 million, has been included in the regulatory framework.

In the same way, the 2020 budget law (L. No. 160/2019) has provided for the allocation of contributions to the municipalities for the years from 2020 to 2024 and to the local entities (i.e. municipalities and provinces) from 2020 to 2034, for definitive and executive planning costs related to interventions for the safety and energy efficiency of educational facilities.

In the outlined overview, an important role for the provision of financial resources essential for the implementation of interventions on school building assets is currently assumed by the NRRP [15] which, for the period 2021–2026, allocates to school building interventions a total of € 9.6 billion, of which € 0.8 for the construction of new schools through the replacement of the already existing ones (M2C3–1.1). In the latter, the focus is on the renovation, safety and energy requalification of buildings, aiming to reduce emissions, to improve their energy performance, to increase the seismic safety, to digitize learning spaces, in order to make public schools innovative, sustainable, safe and inclusive. Due to the different level of degradation and size of the properties to be redeveloped and the amount of the necessary monetary resources to be used connected to the changing needs expressed by the community, the PPP concession is one of the most frequent procedures for implementing interventions.

Nowadays, the renovation of school buildings stock is a common practice to enhance their indoor conditions and to reduce their operation costs. However, the financial feasibility of green schools can appear still ambiguous for the investors and professional subjects. Della Mora et al. (2018) [25] present an experimental study for an energy and structural upgrade methodology, applied to an existing school building in the north-east of Italy and their results show that it is possible to identify a comprehensive energy retrofit at optimal cost, thanks to high energy saving and subsidies. Berardi et al. (2017) [26] assess the effectiveness of different strategies considered for the refurbishment of a school located in the Metropolitan Area of Barcelona. Results show the possibility of reaching the nZEB standard at the end of the refurbishment of this high-energy consuming building.

4 Case Study

The case study concerns a school building located in a small town of the Apulia region (Italy), built in 1993, used for the specific function until 2016, and then abandoned. The main reasons linked to the phenomenon of the disuse of the educational facilities stock can be identified in the reduction of the school population - associated to the demographic trend decline.

In addition to the need to renovate and adapt the existing school assets, the functional reconversion of degraded and/or abandoned buildings is also relevant in order to meet the needs of the local community, to redevelop the public assets and to introduce new functions and services. The considered case study concerns the refurbishment and refunctionalization project of a former school. In particular, the main assumptions: i) the reconversion of the current disused public building into a multifunctional one (i.e. the school function will not be preserved) is planned, ii) a PPP concession will be established, according to which the private subject will bear the costs of the intervention and will become manager of the activities included in the renovated building. The analysis intends to verify the financial feasibility of the initiative through the DCFA, i.e. to assess the convenience from the point of view of the private subject to take part in the assumed operation, by investing its own financial capital, assuming the connected risks (technical and economic).

Starting from an in-depth (socio-economic, morphological, urban, real estate, etc.) analyses of the context in which the intervention is located, a lack of public services in the consolidated and purely residential urban tissue has been attested. The identification of the eligible uses in the reference plot (i.e. public facilities at a territorial/supra-municipal level) has been carried out. Furthermore, the detailed examination of the intrinsic characteristics and the maintenance conditions of the former school building has allowed to observe a poor conservation state both in the internal spaces and in the outdoor ones. The goal of the redevelopment initiative concerns the modification of the property's functional distribution to adapt it to the new uses, the improvement of the energy efficiency and safety, the increase of the finishes quality standard and the arrangement of the total neglected green areas.

4.1 The Functional Reconversion Project

The project hypothesis involves the realization of a multifunctional building in which private and public services are introduced (offices, bookshop, bar, conference rooms) in order to host activities for the communities and/or private sectors. The intended uses have been identified, consistently with those admitted by the regulatory provisions, by developing an analysis of current and forecast supply and demand, in order to detect the main requested functions of the community. It should be outlined that the proposed project solution takes into account the aspects related to the compliance with technical standards, the principle of environmental sustainability, the optimal relationship between the revenues connected to the listed intended uses and the investment and management costs for the private subject. In Fig. 1 the plan with the indication of the new functions is reported. The hypothesis regarding the PPP management of the spaces after the conclusion of the building redevelopment project provides that the offices, the bar and the bookshop will be leased to third subjects, whereas the conference rooms will be directly managed by the investor.

4.2 DCFA Application

With reference to the starting hypothesis related to the PPP procedure implementation, the period of the concession by the Public Administration (owner of the property) to the private subject for the use and the economic exploitation of the new activities after the functional reuse initiative, equal to 30 years has been assumed.

4.2.1 The Investment Costs

In order to verify the financial feasibility of the analysed intervention, the assessment of the investment costs (related to the building refurbishment and green area arrangement) has been carried out by consulting current price lists of public and private works of the Apulia region and the data reported in the "Building typology prices" list [27].

FUNCTIONS		
A	OFFICE	309 m^2
B	BOOKSHOP	230 m^2
C	BAR	187 m^2
D	CONFERENCE ROOM	138 m^2 + 49 m^2
E	TOILET	63 m^2
F	ENTRANCE HALL	193 m^2

Fig. 1. Planned functions and m^2 of gross floor area in the renovated building

The costs have been validated through local operators and construction companies. The total amount of construction costs is equal to € 720,357.26. The technical costs (i.e. the expenses for preliminary surveys, design, works management, testing, etc.) and the general expenses (i.e. the fees for specialized technicians and professionals, the costs of the insurance for the construction phase, etc.) have been calculated in percentage terms with respect to the construction costs (in particular equal to 5% for the technical costs and 4% for the general expenses). For the financing initiative, an assumption on the borrowed capital for the realization of the project has been defined: the 50% of the investment costs (i.e. refurbishment costs and technical and general expenses) is carried out with loan capital considering an interest rate equal to 4.36% to be returned in 10 years and the remaining 50% with own monetary resources.

4.2.2 The Management Costs

The management costs category includes the expenses for the ordinary and extraordinary maintenance (i.e. related to the operations, carried out periodically at more or less long time intervals, necessary to preserve a high level of quality and efficiency of the building for the entire concession period) and the operating costs (i.e. the ordinary maintenance costs to be borne on an annual basis have been determined considering an incidence of 0.3% of the construction costs starting from the first year of the activity phase of the multifunctional building) (it should be highlighted that the ordinary maintenance expenses are considered for all the spaces managed directly by the investor – i.e. the conference rooms -, whereas these costs are not included in the financial analysis for the rented spaces – i.e. the offices, the bar and the bookshop).

With reference to the extraordinary maintenance, it is assumed that every 5 years (starting from the seventh years) these operations will be performed, and their costs have been estimated equal to 5% of the construction costs. To determine the operating costs of the initiative, the expenses to be incurred for each year of management activities have been estimated based on construction costs and rental revenues in percentage terms. The management costs have been then compared with those usually paid for similar intended uses and, eventually, they are adapted according to the local real estate parameters in order to obtain consistent results. The total estimated annual costs for the management of the multifunction building are equal to € 14,856.83/year, except for the years in which extraordinary maintenance will be carried out and in which the management costs will be equal to € 50,874.69.

4.2.3 The Revenues

The assessment of the revenues connected to the hypothesized uses has been carried out considering that i) the offices, the bar and the bookshop will be leased and ii) the conference rooms will be managed directly by investor subject. Therefore, the revenues deriving from the lease of the mentioned spaces have been determined by considering the values range (quotations) of the Real Estate Market Observatory (OMI) of the Italian Revenue Agency's database for the market microzone in which the building is ubicated and the first half of 2023 (latest available data) [28].

The detected value has been validated through consultation with the main operators of the local market for the rental of offices properties. It should be specified that the OMI quotations refer to properties characterized by a "normal" conservation state (i.e. suitable for domestic functions) and not to renovated or new ones, i.e. like the offices of the multifunctional building after the redevelopment. In this sense, the analysed properties will have better structural and internal finishes qualities compared to those ordinarily rented in the reference area. It has therefore assumed that the maximum value found in the reported range can be increased by 40%. This is also to take into account the fact that the rental price will include utilities costs (electricity, heating, internet connection, water, etc.), that will not be paid by the tenant but by the investor. Similarly, for the bar and bookshop the reported OMI quotations for the reference market microzone of the first half of 2023 have been consulted, then validated through a direct market survey and the detected maximum value in the range of reference values has been increased by 20% in order to consider the better maintenance conditions of the designed spaces compared to those ordinarily rented in the area and the inclusion of utility costs not borne by the tenant.

To determine the revenues for conference rooms, the rates to be applied on a daily basis for their use have been examined and an occupancy rate hypothesis has been formulated based on the analysis of the existing and forecast market demand. It should be underlined that the total annual revenues for the daily rental of the conference rooms have been estimated starting from the rates applied in municipalities neighbouring the one in which the intervention is located, as there is currently no similar service. Based on the hypotheses and the identified tariffs, the overall annual revenues in the fully operational phase will be equal to € 109,836.00/year.

4.2.4 Findings

In order to verify the financial feasibility of the initiative through the DCFA implementation, after the investment and management costs and revenues estimation, the cash flows have been determined. The discount rate allows to carry out the actualization operation and, in the analysis, it has been obtained as the sum of three components: the first one is the return that the private operator would obtain by using the invested capital into risk-free alternative investments, the second one concerns the expected inflation over the implementation period of the initiative, the third one is related to the risk premium for the private involved in the initiative. The first two components are determined by using the average annual nominal rate of return on third-year government bonds, i.e. in the present case equal to 4.5% of the long-term treasury bonds (BPT) in February 2023. The third component is assumed as 2.5%, by considering the dynamism of the local real estate market and the specific intervention typology in the interval [2%–3%] in which the rate of the risk premium for real estate investments ordinarily falls. Thus, the discount rate to be used in DCFA is determined equal to 7%.

The obtained outputs attest the financial feasibility of the initiative. In particular, the main performance indicators (Net Present Value - NPV - equal to € 90,248.13, Internal Rate of Return – IRR - equal to 8.07% and the Cost Revenue Ratio – CRR - equal to 1.09) demonstrate the convenience for the private investor to take part in the proposed PPP concession operation. In Fig. 2 the DCFA implementation is shown.

	1	2	3	4	5	6	7	8	9	10	11	12	13	30
Construction costs	360,178.63 €	360,178.63 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	…	- €
Technical and general expenses	32,416.08 €	32,416.08 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	…	- €
Ordinary maintenance	- €	- €	12,860.93 €	17,850.68 €	14,856.83 €	14,856.83 €	14,856.83 €	14,856.83 €	14,856.83 €	14,856.83 €	14,856.83 €	14,856.83 €	…	14,856.83 €
Extraordinary maintenance	- €	- €	- €	- €	- €	- €	36,017.86 €	- €	- €	- €	- €	36,017.86 €	…	- €
Commissions on leases	- €	- €	3,991.80 €	5,987.70 €	- €	- €	- €	- €	- €	- €	- €	- €	…	- €
Insurance	- €	- €	720.36 €	720.36 €	720.36 €	720.36 €	720.36 €	720.36 €	720.36 €	720.36 €	720.36 €	720.36 €	…	720.36 €
Vacancy	- €	- €	798.36 €	1,197.54 €	1,596.72 €	1,596.72 €	1,596.72 €	1,596.72 €	1,596.72 €	1,596.72 €	1,596.72 €	1,596.72 €	…	1,596.72 €
Utilities services	- €	- €	4,790.16 €	7,185.24 €	9,580.32 €	9,580.32 €	9,580.32 €	9,580.32 €	9,580.32 €	9,580.32 €	9,580.32 €	9,580.32 €	…	9,580.32 €
Raw material purchase	- €	- €	399.18 €	598.77 €	798.36 €	798.36 €	798.36 €	798.36 €	798.36 €	798.36 €	798.36 €	798.36 €	…	798.36 €
Financial charges	17,077.87 €	15,678.36 €	14,217.98 €	12,694.07 €	11,103.87 €	9,444.50 €	7,712.94 €	5,906.06 €	4,020.58 €	2,053.08 €				
TOTAL	**409,672.58 €**	**408,273.07 €**	**27,078.91 €**	**30,544.75 €**	**25,960.70 €**	**24,301.33 €**	**58,587.63 €**	**20,762.89 €**	**18,877.41 €**	**16,909.91 €**	**14,856.83 €**	**50,874.69 €**	**…**	**14,856.83 €**
Offices	- €	- €	17,400.00 €	26,100.00 €	34,800.00 €	34,800.00 €	34,800.00 €	34,800.00 €	34,800.00 €	34,800.00 €	34,800.00 €	34,800.00 €	…	34,800.00 €
Bar	- €	- €	10,098.00 €	15,147.00 €	20,196.00 €	20,196.00 €	20,196.00 €	20,196.00 €	20,196.00 €	20,196.00 €	20,196.00 €	20,196.00 €	…	20,196.00 €
Bookshop	- €	- €	12,420.00 €	18,630.00 €	24,840.00 €	24,840.00 €	24,840.00 €	24,840.00 €	24,840.00 €	24,840.00 €	24,840.00 €	24,840.00 €	…	24,840.00 €
Conference room	- €	- €	15,000.00 €	22,500.00 €	30,000.00 €	30,000.00 €	30,000.00 €	30,000.00 €	30,000.00 €	30,000.00 €	30,000.00 €	30,000.00 €	…	30,000.00 €
TOTAL	0.00 €	0.00 €	54,918.00 €	82,377.00 €	109,836.00 €	109,836.00 €	109,836.00 €	109,836.00 €	109,836.00 €	109,836.00 €	109,836.00 €	109,836.00 €	…	109,836.00 €
CASH FLOWS	**-409,672.57 €**	**-408,273.07 €**	**27,839.09 €**	**51,832.25 €**	**83,875.30 €**	**85,534.67 €**	**51,248.37 €**	**89,073.11 €**	**90,958.59 €**	**92,926.09 €**	**94,979.17 €**	**58,961.31 €**	**…**	**94,979.17 €**
IRR	**8.07%**													
NPR	**90,248.13 €**													
CRR	**1.09**													

Fig. 2. Development of the DCFA for the case study

In summary, DCFA offers a comprehensive framework for evaluating the financial feasibility and the risks associated with renovating public school buildings. By considering both the costs and expected cash flows over time, decision-makers can make informed choices that maximize the value of investments in education infrastructure.

5 Conclusions

The redevelopment of school buildings asset is currently strongly relevant, due to the attested needs of recovery of these public properties. Beyond the urge of safety and energy retrofit interventions, the functional reconversion of former and/or abandoned educational facilities has been detected.

The present paper is part of this topic, with a real world DCFA application for the reuse of a disused school located in a small town in Apulia region (Italy), by assuming that the initiative is carried out by a PPP concession procedure. The obtained results show a convenience for the private investor to be involved in the operation. Further insights may concern the improvement of the financial parameter (costs and revenues) included in the analysis by developing more analytical assessments. Furthermore, a sensitivity analysis can be carried out in order to identify the critical variables that can affect the financial sustainability of the investment. Finally, the economic impacts can be considered through the development of Cost Benefit Analysis, in order to verify its feasibility for the local communities [29–31].

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The Role of Financial and Economic Analyses to Support Healthcare Interventions

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Abstract. In the framework of a rising attention paid to the social well-being, an increasing amount of public funding is being allocated to strengthen healthcare systems and to guarantee fair and full access to medical care. Public interventions in the healthcare field are notably intricate, due to the several heterogeneous outcomes impacting on the entire society. The assessment of health programmes and projects is fundamental to determine the appropriateness of a public expenditure from a social perspective. The cost-benefit analysis is recommended as an assessment tool to support the decision-making processes, especially in the healthcare sector. The applicability of this tool is strictly related to the method for the monetary quantification of positive and negative impacts generated by an intervention. Starting from the comparison of the methodologies for this quantification illustrated in the reference literature, the objective of this work concerns the proposal of guidelines useful to monetize the effects associated with interventions in the healthcare sector.

Keywords: economic analysis · monetary approach · healthcare sector

1 Introduction

The COVID-19 pandemic has put a strain on healthcare systems worldwide, which have proved unsuitable to meet all the needs of the entire population, especially in such challenging situation. The considerable difficulties detected during the pandemic have highlighted the importance of protecting human health and welfare, preventing risks and being able to face unexpected threats.

For this purpose, the adoption of long-term perspective actions is necessary, aiming at the full, equitable and constant enjoyment of the right to health. Huge amounts of funding have been allocated by the institutions, such as the European Union (EU) and its member countries, with the aim of implementing cooperation, strengthening health systems and training healthcare workforce. With the EU4Health programme [1], the EU has allocated a €5.3 billion budget during the 2021–2027 period to increase preparedness and responsiveness to health threats and to improve the public health systems' efficiency. Italy has invested €15.62 billion [2] on healthcare sector in the context of the Mission

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6 of the National Recovery and Resilience Plan (NRRP) [3]. The goal is to enhance the prevention and care capacity of the national health system, promoting the use of innovative technologies and ensuring fair access to medical care for all citizens.

Health investment projects are considerably intricate, since they deal with important challenges and may have significant medium- to long-term impacts on a large territorial scale. These impacts should be predicted with specific decision-support tools and constantly monitored during the interventions' implementation. In this framework, detailed analyses and economic evaluations have become increasingly important to assess the social desirability of healthcare resources allocation. The World Health Organization (WHO) proposes a practical approach, called Health Impact Assessment (HIA) [4], to estimate the potential health effects on a population of a policy, programme, or project. The five-step procedure helps to achieve foresight in social decision-making.

The Economic Appraisal Vademecum 2021–2027 (EAV) [5] reports some economic evaluation methods usually applied to the health projects. Among these, the Least-Cost Analysis (LCA) and the Cost-Effectiveness Analysis (CEA) are recommended to compare previously defined options with the same objective, in presence of a single project outcome. The LCA is mainly implemented when a pre-defined result has to be achieved, in order to choose a technical component among different alternatives by comparing their costs. The CEA is used to compare different project options pursuing the same result with various intensities. The Cost-Utility Analysis (CUA) is suitable for projects generating gains in the form of reduced mortality and improved quality of life or reduced disability. Another decision-making tool is the Multi-Criteria Decision Analysis (MCDA), typically used for the option analysis and selection, also useful when the quantification of the project outcomes and their aggregation in an economic computing is difficult to perform. While MCDA allows to manage heterogeneous objectives and criteria together, the Cost-Benefits Analysis (CBA) is focused on a specific criterion which is the maximizing of the social welfare. The main challenge in CBA is the monetary conversion of different types of benefits, such as health outcomes and collective resources savings, to make them comparable with the costs of the project.

The previously listed techniques adopt an ascending width of perspective. When assessing a health program through CEA, the effects are measured in specific disease symptoms. With CUA, the effects are quantified in Quality Adjusted Life Years (QALYs), a more comprehensive measure allowing to compare any healthcare intervention: it combines mortality and morbidity by assigning a weight to each health state (from 0, corresponding to death, to 1, representing full health), and multiplying it with its duration. The CUA can be converted into CBA, by giving the QALY a constant price. The CBA allows to consider any type of priced social effect, turning out to be the most appropriate method to establish if an expenditure of public resources is convenient for the society, since (i) its outputs are priced thus comparable to the costs and (ii) the effects on everyone are considered [6]. These peculiarities make CBA suitable for the assessment of health investment proposals. Additionally, it is important to mention that in the 2014–2020 programming period, the implementation of CBA was mandatory for major projects financed by the European Regional Development Fund or the Cohesion Fund, as stated by the Guide to CBA [7]. In the 2021–2027 programming period [5] the CBA use is voluntary, and a set of alternative assessment tools, as those previously presented, are recommended in specific conditions. Nevertheless, the European Commission still strongly recommends the CBA among the economic appraisal methodologies for its robust, objective and evidence-based analytical framework for the evaluation of the projects and the identification of welfare-maximizing ones.

2 Aim

This research pursues the goal of verifying the applicability of the Financial and Economic Analyses as appraisal tools in the healthcare field, identifying potential and limits of its implementation in such an intricate context.

The current relevance of the issue mainly consists in the challenging identification of all the benefits having an impact on society. The remarkable complexity of this stage lies in the risk of uncertainty and incompleteness affecting their quantification in monetary terms. In fact, as reported in [8], several studies related to the CBA application to the health sector have achieved a partial result, not assigning monetary value to the health outcomes. The EAV presents some practices for the monetary evaluation (through Willingness To Pay - WTP, Human Capital Approach - HCA, alternative costs saved) of some typical benefits (e.g. the reduced mortality, the reduced morbidity, the reduced hospitalizations) resulting from health interventions.

Initially, the most common approach to associate money values to health outcomes in the CBA literature of healthcare was the HCA. According to the HCA, the changes in the health status are computed in monetary terms based on estimated productivity gains or losses. The alternative approach, more recently proposed, is the estimation of individuals' WTP for the execution of the intervention proposal. The WTP can be indirectly or directly measured. Many studies have used the Revealed Preference (RP) approach for the indirect measurement of the WTP, which allows the preferences assessment from actual choices. Since the market data are difficult to obtain, the academic attention has been shifted to the Stated Preference (SP) approach which allows the direct estimation of the WTP by means of choice responses about hypothetical scenarios proposed through survey methods. Two typical examples of the SP approach are Contingent Valuation (CV), directly asking individuals to attach monetary values to non-market goods in a hypothetical situation, and Choice Experiment (CE), consisting of choice tasks appropriately structured to reveal the decisions determinants.

Due to the presence of different and multiple costs and benefits, there isn't a univocal CBA application tool for their quantification in health projects; this limit implies the risk that most benefits are not to be translated into monetary terms or to not be considered at all, underestimating the performance indicators. The objective of this paper is to identify guidelines for such quantification, in order to strengthen the validity of the financial and economic analyses implementation in the field of health investments, by carrying out an analysis of the scientific literature on this topic.

3 Literature Review

The analysis of the scientific literature on the economic evaluation of public healthcare investments allows to explore the several ways used for monetizing their effects.

A categorization of these investments is here proposed (see Fig. 1), starting from the literature results [9, 10]. In particular, the financial resources invested in the healthcare sector can be allocated for the implementation of Disease-Specific (DS) programs and Health-Related (HR) ones. The DS approach is focused on the reduction of the impact of a particular illness, through the implementation of measures aimed to prevent, detect and treat it in a more efficient way. Differently, a HR program is aimed at obtaining a better health status of the population through an improved organization of medical care provision: enhanced or additional infrastructures and services, increased number and preparation of the medical staff, new technologies and modalities to provide services.

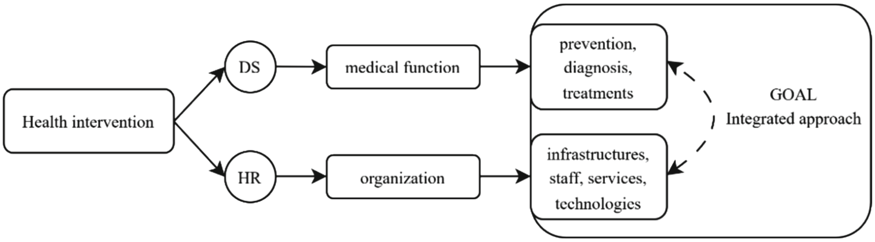

Fig. 1. Categorization of health interventions approach (Authors' elaboration).

The scientific literature was analyzed in terms of the (i) investment typology (DS or HR), (ii) specific purpose of the allocated resources, (iii) measure unit of the social benefits of the program, (iv) method applied for the monetary conversion.

Three types of DS programs can be identified based on their specific medical purpose. The focus can be placed on the implementation of prevention measures [11, 12]; other investments are aimed to ease the diagnosis stage [13]; the last and most detected type of intervention is the treatment-oriented one [14–19]. In the framework of HR interventions, one of the less frequently assessed initiative typologies, with only 3 papers dealing with it [20–22], is the realization of infrastructures. This finding can be linked to the complexity of the process underlying this investments kind. The implementation of new or better services to be provided to the patients (including the introduction of different way of equipment) is mainly investigated [23–30], with a special attention to new medical technologies [27–30].

Regarding the measure of the benefits deriving from the implementation of the assessed health program, several Authors have mentioned the savings in terms of time for patients, caregivers and service providers [6, 23, 24, 27–30]. The identification of the same benefit doesn't always imply the adoption of the same method of monetary quantification. For example, [6, 28–30] measured the time savings in terms of productivity loss (avoided or reduced) and productivity gain or savings; [23] calculated the change in consumers surplus implementing data estimated through a CE survey; [24] adopted the travel cost method and collected data by means of a discrete choice model survey; [27, 28] quantified the time savings in terms of averted expenditures; [29] computed some time savings in terms of the consequent potential revenue and some others in non-monetary terms. This is not the only case in which non-monetized social benefits are considered: in [30] the stress reductions and the increased abilities, control and quality of life have not been converted into money and in [13] the reduced burden of disease has been quantified in Disability-Adjusted Life Years (DALYs). DALYs are the combination of Years of Life with Disability (YLDs), which multiplies the number of cases in a population for the duration and the weight of the disability produced by a specific health condition, and the Years of Life Lost (YLLs) due to premature death, which considers the number of deaths and the life expectancy at the age of death. Despite QALYs and DALYs both represent combined measures including quantity and quality of health, these two approaches can produce very different results.

In general, for the monetary conversion of the positive effects, the WTP approach has been frequently applied [6, 14, 17, 18, 25, 26]. Several Authors have monetized the benefits by computing the direct or indirect cost savings [6, 11–13, 15, 16, 19, 20, 23, 24, 27, 28, 30]. Alternatively, [6] has priced the increase in QALYs by using a Value of a Statistical Life (VSL) estimated through WTP for mortality risk reduction; [16] calculated a public value Return On Investment (ROI) using a value per QALY equal to the Value of a Statistical Life Year (VSLY) suggested from the government in the reference year. The difference between the VSL and the VSLY approaches consists in the different value associated to each life saved: the former attributes equal value, while the latter assigns a value which is proportional to the life expectancy.

All the information collected from the analyzed papers is synthetically reported in Table 1 as concerns DS interventions, and in Table 2 with regard to HR ones. This summary can represent a useful indication for the application of CBA, especially for the deployment of the economic analysis in the context of public health investments.

4 Conclusions

In the framework of a rising attention to social well-being, an increasing amount of public funding is being allocated to boost the healthcare systems efficiency and efficacy, and to guarantee all citizens fair and full access to medical care.

The comparison of benefits and costs resulting from the implementation of a programme or a project has a key role in the determination of its social desirability. The identification, the quantification and the conversion in monetary terms of the economic benefits affecting society as a whole are very intricate tasks. The economic benefits, such as improvement of the health status and quality of life, are sometimes overlooked for extreme cautiousness. Unfortunately, this makes projects in the health sector not comparable with other types of public intervention [31, 32], as it underestimates the positive effects. This simplification partially delegitimizes the application of CBA in the health field. Conversely, the identification of guidelines for the quantification of the economic benefits is necessary to enhance the application of this appraisal tool in such a challenging framework. A limitation of this study lies in the non-highlighting of pros and cons arising from the different methods and metrics of monetary evaluation which were detected. This could allow to identify which among them show the strongest validity and the wider applicability. A future development of this work should fill this gap and provide an applicative case study. The goal will also be to promote an integrated approach, being able to link the disease-specific point of view and the health-related one, in order to add value to the allocated financial resources.

Table 1. Measurement in monetary terms of Disease-Specific (DS) interventions' effects.

Typology of DS investment	Economic benefit	Method of monetary evaluation	Ref.
Interventions for reducing dementia symptoms	Increased QALYs for patients	WTP for mortality risk reduction (QALYs priced by using VSL)	6
	Increased chances of independent living for patients	Cost savings for caregivers and government	6
	Reduced elder abuse	WTP, measured through willingness to persecute abusers	6
	Saved time for caregivers	Time savings (priced with labor market valuations)	6
Prevention program for injuries due to assault, gunshots, outdoor falls, and traffic	Injuries prevented and reduced demand for emergency services	Cost savings due to reduced medical spending	11
Control program for nosocomial infections	Prevented nosocomial infections	Charge savings and medical costs savings	12
Campaign to reduce pre-hospital delay time in response to heart attack symptoms	Increased functional outcomes and quality of life	Reduction in informal care costs	13
	Reduced illness and premature mortality	Reduction in productivity loss (HCA)	13
	Reduced burden of disease DALYs	Non-monetary	13
New medication to treat depression	Reduced risk of adverse effects	WTP for risk reductions, measured with CV method	14
Modified therapeutic community for mentally ill chemical abusers	Reduced number of criminal acts	Cost savings, based on the total social cost of each crime	15
	Increased productivity	Increased earnings, due to incremental hours of work	15
	Reduced utilization of other healthcare services	Cost savings	15
New tobacco dependency treatment service	Reduced levels of smoking-caused disease	Treatment cost savings and fiscal outputs	16

(*continued*)

Table 1. (*continued*)

Typology of DS investment	Economic benefit	Method of monetary evaluation	Ref.
	Increase in QALYs	Public value ROI (using a value per QALY of £60000)	16
In vitro fertilization (IVF) program for infertility treatment	Increased chance of having a child	WTP, measured through CV survey	17
Healthcare program regarding atherosclerosis	Reduced angina pectoris attacks rates	WTP for risk reductions, measured with CV method	18
Rehabilitation service for stroke	Reduced disability burden	Tax recovery for the government	19
		Savings from disability payments for government	19

Table 2. Measurement in monetary terms of Health-Related (HR) interventions' effects.

Typology of HR investment	Economic benefit	Method of monetary evaluation	Ref.
Territorial facilities for decentralized access to basic healthcare	Improved accessibility to basic healthcare	WTP for improved accessibility, measured relying on market demand (SP approach) and observed consumer surplus gain accruing to the community (RP approach)	20
Construction of polyclinics	Social effects	Fiscal multipliers, calculated through regression methodology	21
Territorial facilities for decentralized access to healthcare	Social effects	Conversion Factors	22
Specialization in departments of obstetrics and gynecology	Reduction of cost of a birth	Change in consumer surplus for the local community, estimated using the data from a CE survey	23
	Reduction of waiting time for a medical exam		23
	Increase of the number of doctors and nursing staffs		23

(*continued*)

Note. The research has been developed within the project "MISTRAL - a toolkit for dynaMic health Impact analysiS to predicT disability-Related costs in the Ag"-

Table 2. (*continued*)

Typology of HR investment	Economic benefit	Method of monetary evaluation	Ref.
Mobile units for decentralized access to mammographic screening	Reduction in medical costs	Travel cost method, using data from a discrete choice model survey. (Compensating variation associated with the reduction in access costs)	24
	Reduction in travel costs for women		24
	Reduction in time costs for women		24
Supplemental healthcare services	Reduction in the risk of being assigned an inexperienced surgeon after a long wait	WTP, measured through CV survey	25
Health services quality improvement	Improvement of healthcare quality on 7 attributes	WTP for improvements, measured with CV questionnaire	26
Teledermatology service	Savings of consultant and patient time	Cost savings	27
	Saving of patient travel cost	Cost savings	27
	Value of expertise acquired through practice by general practitioners	Cost of equivalent training	27
Digital radiology systems	Increased speed of access to records for the diagnostician	Increased productivity and greater income	28
	Reduced length of stay for the referring physician	Increased productivity	28
	Shorter examination times for the patient	Reduced travel and attendance costs	28
	Increased staff morale and improved staff retention	Cost savings	28
	Improved diagnosis	Non-monetary	28
Picture Archive and Communication Systems (PACS)	Time saved for the referring physician	Productivity gain (potential revenue due to increased patient care)	29
	Time saved for referring physician support staff	Productivity savings (based on assumed hourly wage rate)	29
	Labor time saved	Non-monetary	29

(*continued*)

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Table 2. (*continued*)

Typology of HR investment	Economic benefit	Method of monetary evaluation	Ref.
Telepsychiatry service	Decreased travel for patient (time saved and stress avoided)	Travel cost and productivity loss avoided	30
	Decreased travel for psychiatrist (avoided non-productive time and stress)	Productivity loss avoided; increased case-load	30
	Decreased travel for physician/ local service provider (avoided stress and increased ability to interact)	Non-monetary	30
	Decreased waiting time for patient	Productivity loss avoided	30
	Decreased waiting time for psychiatrist	Potential for decrease in consultations/ hospitalizations	30
	Decreased waiting time for physician/ local service provider	Potential for decrease in visits/ payments; potential to increase number of mental health clients	30
	Client choice and control/ increased ability to manage in the community	Non-monetary	30
	Increased quality of life	Non-monetary	30

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A Methodological Approach for the Analysis of the Effects of Polluting Industrial Sites on the Real Estate Market

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Abstract. Urban areas with industrial sites face challenges related to their negative environmental and community impacts, as well as the economic implications of these issues. In fact, these challenges may influence the behavior of residents with respect to their housing choices, generating broader effects on real estate market dynamics. Understanding the impact that the presence of polluting sites has on real estate prices is critical to allow decision makers to make informed choices in complex situations affected by the influence of these sites. The purpose of this work is to define a methodological approach for investigating the relationships between the presence of polluting sites and the real estate market. The proposed approach constitutes a valid reference for the market analysis in order to develop effective assessments of the interventions to be carried out on the territory.

Keywords: Polluting sites · Real estate market · Real estate variables · Environmental factors · Socio-economic features · Econometric techniques

1 Introduction

The presence of polluting sites in urban areas can lead to several negative impacts on both the local environment and social welfare, which in turn can lead to different economic impacts [1].

Polluting sites generate externalities that contribute to environmental degradation. Depending on the specific characteristics of the polluting site, these impacts relate to soil and water quality, air pollution and other significant health risks [2]. In addition, the polluting sites can have a negative impact on the way of living in the neighborhood, its urban quality level and the wider environment [3]. In fact, people in industrial cities regularly face health risks associated with poor environmental conditions due to increased

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levels of pollution: these problems often influence housing and rental market dynamics in these areas [4].

Understanding these issues is essential for policymakers and all public and private subjects involved into urban development plans, such as planners and/or private investors who make compromises between community benefits, economic development and private interests. Determining the influence of the presence of polluting sites on the real estate market provides useful information on how much residents are willing to accept or tolerate for selling prices and rental fees, due to the presence of these sites. In addition, this quantification serves to assess the potential benefits of hypothetical closure or renovation strategies, thereby guiding in an efficient way territorial policy [1].

The present work is part of the outlined framework. Its aim is to establish a methodological approach that can be employed for assessing the impacts of polluting sites on the real estate market. The reminder of the paper is as follows: in Sect. 2 the proposed approach is described in each phase and in Sect. 3 the conclusions are discussed.

2 Methodological Approach

The proposed approach consists of six operational steps, which are below outlined.

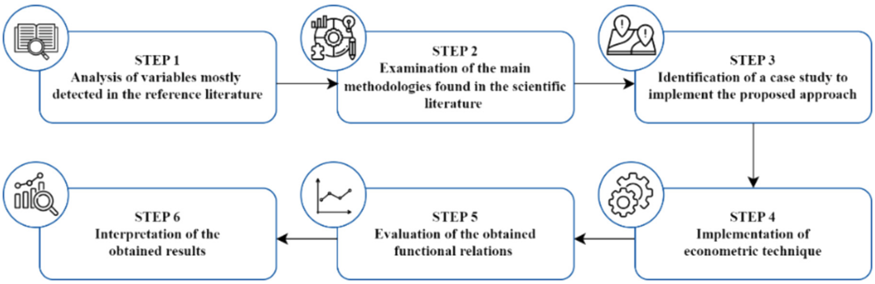

Fig. 1. Summary of the steps of the proposed methodological approach

According to Fig. 1, the methodology consists of:

1. The analysis of the existing literature for identifying the most commonly used variables to study the relationships between property values and the presence of polluting sites;
2. The exam of the main employed methodologies in the reference national and international literature for similar topics, or the identification and selection of the variables that influence the market value of properties. This phase is essential to identify the appropriate econometric technique to be used in the further steps;
3. The definition of a case study to implement the proposed approach. This step consists of the creation of a database composed of a sample of n newly bought properties of known selling prices and the related variables identified after conducting the phase 1. This process makes it possible to construct a database that reports the specific value of each variable for each considered property;

4. The selection of the econometric technique to implement in the case study for analyzing the existent functional relationships between property values and the chosen variables that contribute to the formation of the selling prices. It should be highlighted that the dependent variable can be represented by the unit selling price of the *i-th* property. After that, the determination of statistical indicators to assess the accuracy of the implemented econometric model is carried out;
5. The analysis of the obtained results. In particular, the variables selected by the econometric technique as the most influencing on the real estate prices and the observed functional relationships between them and the property values. Moreover, the type of the functional relationships, the correlation levels and the marginal contributions are determined;
6. The validation of the coherence, in terms of empirical evidence, of the obtained results and the discussion on the main advantages and limits of the proposed approach.

2.1 Analysis of Mostly Detected Variables in the Reference Literature

A large body of academic research has focused on assessing the influence of various types of polluting sites on property values in different geographical contexts. The first step in the outlined methodological approach represents a key operation in providing support for the definition of the variables to be considered in the present study, with reference to the polluting sites and the real estate market dynamics. This step allows to identify three general categories of variables, each delineated according to the measured specific aspects: (i) intrinsic and extrinsic real estate variables, (ii) socio-economic factors, and (iii) environmental features.

2.1.1 Intrinsic and Extrinsic Real Estate Variables

The first category concerns the variables that measure specific aspects of the properties to be valued and can be classified into intrinsic and extrinsic variables. Intrinsic variables allow the measurement of the characteristics of the property itself. Among these ones, the most used are: (i) the price of the property [5–7], (ii) the total floor area of the dwelling [8–10], (iii) the age of the building [11, 12], and (iv) the number of bathrooms and bedrooms [13, 14]. However, the property price is not only a function of intrinsic features, but also of extrinsic features of the surrounding urban context (P = f (I, E)). Among these, the most common are: (i) distance to the nearest park [15, 16], (ii) distance to the Central Business District [9, 14], and (iii) distance from the railway [17, 18].

2.1.2 Socio-Economic Factors

Socio-economic variables measure the economic and social levels of the urban area in which the properties are ubicated. These variables provide insight into demographic characteristics, income levels, quality of the educational system, crime rates, and other relevant information essential to assessing the quality of the surrounding context. Among the retrieved variables of this type, the most commonly used in the considered literature are: (i) age of the household [10, 19], (ii) education level [19, 20], and (iii) income level [21, 22].

2.1.3 Environmental Variables

The category of environmental variables includes the ones employed for taking into account and addressing the presence of polluting sites and their effects on property values. In particular, the most frequently used variable for this issue is the distance, expressed in kilometers, of the property from the polluting site [4, 6–9]. The distance from the polluting site is generally considered as a suitable proxy variable to measure the effects of the polluting site presence. In addition to distance, other kind of environmental issues attempt to quantify air quality by assessing levels of ozone, carbon monoxide, nitrogen oxides, and relevant polluting agents considered hazardous to human health [7, 18, 28, 45]. It may vary according to the specific industrial activity and pollution emissions related to the site. For example, studies of the presence of incinerators [23–25], industrial sites in general [2, 16, 17], and brownfields [20, 26, 27] include only distance as an environmental variable in their analyses. In contrast, landfill-related studies. Ham et al. (2013) [28] examine the impact of landfills on property values in Birmingham, England, in a scenario where properties are often ubicated in close proximity to multiple landfills, by considering also other factors in addition to distance. These factors include measured levels of environmental pollutants such as NO_2 and CO. In addition, for landfills, other Authors consider not only the distance variable but also the size and volume of waste accepted at the landfill to assess its impact on property values [29, 30]. With respect to studies on the impacts of steel mills, some of them consider exclusively the distance between the site and properties as an environmental characteristic [4, 31]. For the city of Taranto (Italy), air and noise quality in addition to distance from the steel mill are often taken into account as environmental variables [18, 32].

Table 1 provides an overview of the most used variables in the analyzed studies. Each variable is followed by a brief description and references to the articles in which it was used. In order to provide a clear synthesis of the entire sample of scientific literature analyzed, only those variables that appeared in at least four scientific contributions are reported.

Table 1. The most common variables in the reviewed studies

Variables	References
Intrinsic real estate variables	
Transaction price of the property (Reference country currency)	2, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 35, 39, 40, 41, 43, 45
Asking price of the property (Reference country currency)	4, 10, 18, 23, 32
Transaction date (Date)	8, 9, 25, 28, 30, 40, 43
Floor area of the house (m^2)	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 20, 21, 23, 24, 26, 28, 30, 31, 35, 39, 40, 41, 42, 43, 44, 45

(*continued*)

Table 1. (*continued*)

Variables	References
Detached property (Dummy variable)	2, 4, 10, 16, 17, 18, 24, 25, 28, 30
Age of the house (Count)	8, 9, 10, 11, 12, 13, 14, 17, 19, 20, 21, 22, 23, 26, 27, 28, 30, 29, 40, 41, 42, 43, 44
Number of rooms (Count)	6, 7, 8, 16, 18, 20, 22, 39, 40
Number of bedrooms (Count)	4, 5, 9, 11, 13, 14, 15, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 35, 43, 45
Number of bathrooms (Count)	4, 6, 8, 9, 11, 13, 14, 16, 18, 20, 21, 23, 25, 26, 27, 28, 29, 30, 32, 42, 44, 45
Floor level (Count)	4, 5, 6, 12, 15, 20, 23, 31
Number of floors (Count)	8, 13, 14, 21, 28, 29, 40, 45
Decoration (Dummy variable)	12, 23, 30, 45
Quality of the building (Dummy variable)	4, 5, 16, 18, 20, 22, 26, 30, 35, 39, 44
Balcony and Terrace (Dummy variable)	4, 7, 11, 16, 18, 32, 45
Parcel (lot) area (m^2)	2, 11, 16, 19, 20, 21, 22, 26, 27, 29, 30, 35, 39, 40, 42, 43, 44, 45
Presence of fireplace (Dummy variable)	8, 9, 29, 35, 40
Presence of full basement (Dummy variable)	11, 14, 16, 21, 30, 35, 39
Presence of garage (Dummy variable)	4, 9, 10, 14, 17, 18, 21, 28, 31, 32, 40, 44
Number of garages (Count)	2, 11, 20, 25, 29
Presence of garden area (Dummy variable)	4, 17, 18, 25, 31, 32, 45
Presence of elevator (Dummy variable)	4, 10, 16, 36
Central air conditioning (Dummy variable)	8, 9, 14, 17, 20, 27, 29, 30

(*continued*)

Table 1. (*continued*)

Variables	References
Extrinsic real estate variables	
Distance to the nearest park (km or min)	5, 8, 12, 15, 16, 24, 26, 28, 35
Distance to CBD (km or min)	4, 15, 16, 20, 23, 24, 28, 35
Distance to the railway (km or min)	4, 8, 17, 18, 28, 35
Distance to highway (km)	8, 17, 20, 35, 39, 43, 44
Distance to school (km)	12, 23, 28, 39, 45
Distance to shopping center (km)	5, 12, 23, 28, 39, 44
Socioeconomic variables	
Age of the households (Count)	5, 10, 16, 19, 28
Size of family (Count)	5, 6, 10, 19
Educational level (%)	5, 9, 10, 19, 20
Income level (Count)	5, 9, 10, 19, 20, 21, 22
Unemployment rate (%)	7, 9, 28, 39
Environmental variables	
Distance from the polluting site (km)	4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 35, 39, 40, 41, 42, 43
Scale of the polluting site (hectars/dummy)	12, 17, 27
Environmental polluters ($\mu g/m^3$)	7, 18, 28, 45

2.2 Exam of the Main Employed Methodologies in the Reference National and International Literature

Among the generally employed methodologies in the considered sample of scientific literature, a common approach is the Stated Preference (SP) method [33]. This technique uses surveys to assess individual preferences by presenting respondents with hypothetical scenarios to assess their willingness to pay for changes in environmental quality. Guignet et al. (2015) [34] use a questionnaire to examine perceptions of the risk of death from air pollution among householders in the United Kingdom and Italy. Respondents were asked to choose between two housing scenarios with identical characteristics, differing only in the mortality risk associated with air pollution and the price of housing. In addition, the SP method is often used in combination with the Revealed Preference (RP) method, which allows individuals' preferences to be assessed through direct observation of their behavior [35].

Within SP methods, another survey-based approach used in the reviewed articles is Contingent Valuation (CV) [2, 36]. This method, a specific application of SP, is used to estimate the economic value that individuals place on goods or services that are not traded in the market, particularly in the field of environmental economics. In the United States, Simons et al. (2005) [37] used this methodology to assess the impact of leaking underground storage tanks (LUST) on property values. Respondents were asked about the amount they would be willing to pay for a home with similar characteristics to their current residence, considering three scenarios with varying intensities of LUST leaks.

From the literature analysis, it is evident that the most commonly used methodology for analyses with objectives similar to those of this paper is the Hedonic Price Method (HPM) [5, 28, 38]. This method facilitates the measurement of the impact of various externalities on property values, based on the concept that the value of an asset is derived from its component attributes [22, 39, 40]. Applied to real estate, this means that the value of a property is the function of its intrinsic and extrinsic attributes [6, 7, 23].

In order to assess the implicit prices of these attributes, HPM typically uses regression models, which can take various forms, such as linear, multiple linear, or logarithmic. In a regression model, a dependent variable (the price of the property) is regressed on independent variables (the attributes under consideration) [41, 42]. The application of HPM is advantageous for quantifying the effects associated with negative externalities resulting from the presence of polluting sites [43, 44]. This methodology provides insight into how the distance of properties from such sites affects property values [8, 30, 31, 35].

In addition, HPM is often integrated with Geographic Information Systems (GIS) to better understand the impact of location attributes on property values. This integration enables spatial analysis of property data, providing valuable insight into the spatial distribution of property values in relation to environmental factors [11, 20, 45].

Among the regression techniques, the Evolutionary Polynomial Regression (EPR) stands out as a powerful tool for identifying the most influential factors in the dynamics of property price formation [46, 47]. EPR is a hybrid technique that combines the features of a numerical regression system with a multiobjective genetic algorithm. This integration allows EPR to explore and identify the most optimal mathematical structures capable of describing the phenomenon under analysis [48]. In particular, the iterative nature of the genetic algorithm used by EPR facilitates the discovery of a mathematical expression that best represents the phenomenon under investigation, without the need for an a priori definition of the mathematical structure.

3 Conclusions

The presence of polluting sites is extremely relevant in the actual context of environmental pollution reduction and sustainable development models for urban areas.

The aim of the work has been to define a methodological approach to investigate the relationships between the presence of polluting sites and the real estate market.

The developed approach led to the definition of an operational procedure divided into six steps, of which the first two were examined in detail, since they were the subject of a study already in progress. The first step involved the study of variables used in the literature to assess the impact of polluting sites on the real estate market. The development of this step contributed to the formulation of an initial framework by revealing that, among the environmental variables used in such kind of assessments, the distance between a property and the polluting site emerges as the most frequently used variable in the studies analyzed. The second step focused on the analysis of the methodologies implemented in the studies with similar objectives to the present one. From this analysis, HPM has emerged as the most frequently used methodology to assess the impact of different externalities on real estate prices. The analysis of these two steps has allowed to the definition of the initial results, which are useful for understanding the elements to be considered in the implementation of the methodology in the subsequent steps.

One of the main advantages of the proposed methodological approach is its flexibility. In fact, this methodology can be easily used to assess the real estate market variation produced by the presence of polluting sites—of different industrial activities, size and relevance and in different contexts.

The proposed methodology can provide valuable support in complex situations where decision makers need to find a balance between economic development and the potential negative impacts of associated pollution on public health and community well-being.

Future research developments may include the application of the proposed methodology to national and international context. With reference to the Italian territory, the methodology may be implemented to the specific case of the city of Taranto, where the largest steel mill in Europe (ILVA) is ubicated. The main reason is that in recent years population displacement from areas close to the industrial site to other areas with better environmental quality has been observed [32]. The analysis of the effects of the presence of the ILVA on the local real estate market assumes a relevant role for the definition of targeted policies for the sustainable urban development [49–54].

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A Methodological Approach for the Structuring of a Questionnaire to Investigate the Perceptions of the Community in Polluted Urban Areas

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Abstract. The consequences of the presence of an industrial site in a residential area are manifold. The pollution associated with the proximity to these facilities represents a major risk to the health and well-being of the community. The degradation of the environmental quality of an urban area leads the population to make conscious choices about where they live and to seek out unpolluted urban portions. This attitude has inevitable effects on the dynamics of the housing market and, more generally, on the economy of the area. This work aims to outline a methodological approach that is functional to the structuring of a questionnaire divided into three operational phases. The practical implication of the questionnaire submission is *i)* to study the relationship between industrial sites and real estate market and *ii)* to provide data to support decision-makers in developing strategies and policies for intervention on the territory.

Keywords: questionnaire · industrial sites · polluted areas · real estate market · Willingness To Pay

1 Introduction

The presence of industrial sites in the residential areas and the associated pollution are a matter of concern and reflection due to the environmental and economic impact on the local community [1]. Indeed, industrial facilities pose a risk to the urban systems users mainly because of the health implications. The pollution resulting from their presence often extends beyond the boundaries of the plant, with consequences for the air and water quality of the surrounding areas. In this sense, during the last decades, increasing attention has been paid to the human health and environmental effects caused by these sites in the residential areas [2]. This issue is of particular importance in the cities where the plants are located since the impact on health resulting from a reduction in environmental quality leads the users to move away from this type of context by making

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different housing choices [3]. Therefore, this behavior strongly influences the dynamics of the real estate market, as residential properties located near the production structures are subject to a decrease in market value due to a reduction in demand and an increase in time on the market [4]. Furthermore, the reduction in income levels in neighborhoods exposed to environmental problems represents a crucial question. Generally, the city portions characterized by poor environmental quality face a large number of challenges, among which are the reduction in the income level of residents and the gradual local economic slowdown. In the outlined framework, the community's reactions to the polluted urban contexts are strongly connected to a series of knock-on effects with more or less significant repercussions for the local economy. In this sense, it is necessary to understand the collective perception of pollution, which is often influenced by personal beliefs, socio-demographic variables, and annoyance [5].

The perception of the risk associated with pollution is a fundamental aspect both for analyzing the influence of the industrial sites on the real estate market dynamics and for successfully orienting the policies and intervention strategies [6]. The proper assessment of the environmental damage caused by the reduction in the well-being of the community supports the decision-makers to know the society's perception and the possible effects of territorial policies aimed at managing and mitigating the issues associated with the industrial site's presence. An effective assessment of the consequences of polluted areas on the territory, therefore, requires a holistic approach able to integrate environmental and socio-economic aspects and to actively involve the communities.

The present work is related to the context described above. The aim is to propose a methodological approach to support the evaluation of the impacts of the industrial site's in the residential real estate market through the structuring of a targeted questionnaire.

2 Phases of Questionnaire Design

The proposed methodological approach for structuring the questionnaire has two main objectives: i) collect information to assess the impact of the presence of a polluted site in an urban area on real estate market dynamics; ii) detect socio-economic data that are useful for defining decision support models to guide interventions in the territory and to implement effective risk management strategies. It comprises three main phases (Fig. 1) described below.

The first phase involves the *identification of issues that describe the relationship between polluting sites and real estate market dynamics*. This phase is essential for identifying the categories of questions to be included in the questionnaire.

The second phase involves the *analysis of the main sources*, both official documents used by public statistical agencies operating at national and European levels and the references in the literature. This operation aims to define a descriptive framework of how the questions should be formulated.

The *definition of the structure of the questions* is the third step of the proposed methodological approach. Specifically, the analysis of scientific literature with objectives similar to those of the present research and the analysis of questionnaires used by official statistical agencies made it possible to derive information useful for understanding how the questions were structured. Some questions were taken from the analyzed references and, to best approach the purpose of the research, a set of questions was structured through the use of Contingent Valuation (CV), an approach based on Stated Preferences (SP) [7]. The purpose of the third phase is therefore to draw up the final questionnaire.

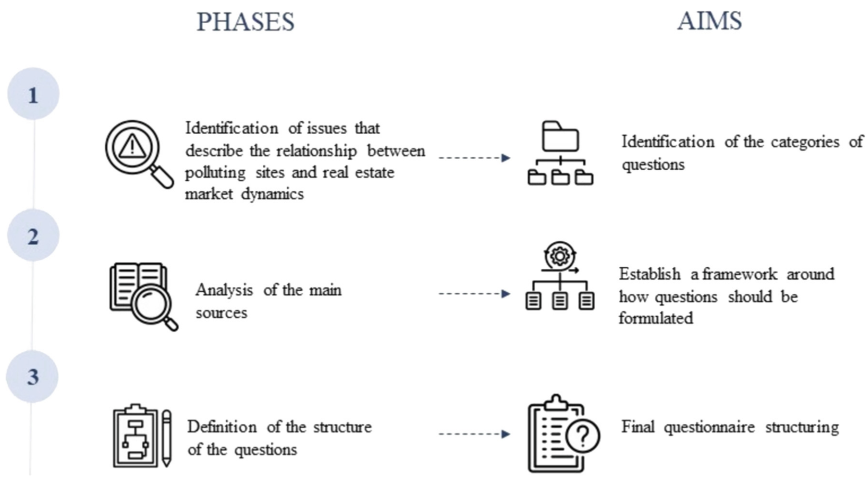

Fig. 1. Phases and aims of each phase of the proposed methodological approach

2.1 Phase 1: Identification of Issues that Describe the Relationship Between Polluting Sites and Real Estate Market Dynamics

The aim of the first phase is to define the categories of questions to be included in the questionnaire. This will be achieved through the analysis of quantitative and qualitative aspects that can describe the impact that the presence of polluting sites in urban areas has on the dynamics of the real estate market. In the present work, the definition of the categories of questions is carried out taking into account: i) the interests of the stakeholders involved in the development of strategic policies to be implemented for effective regeneration and the feasibility check of projects aimed at the sustainable development of territories, and ii) the academic literature on the subject.

In designing a new questionnaire or borrowing a standardized one, it is necessary to develop a strategy that takes into account both the fixed purposes and the target population to which the questionnaire will be submitted. The questions should also be organized in groups and follow a logical sequence [8, 9] that allows the respondent to enter the research topic in a step-by-step manner.

By recalling the goal of the present study, the most suitable categories of questions are: i) personal and social data, ii) property and income situation, iii) data related to the house property, iv) data related to the characteristics of the reference context, v) Willingness To Pay (WTP) to assess the perceived risk associated with the proximity to the industrial site. In Fig. 2 the categories of questions are reported.

The first two categories of questions are designed in order to have outcomes able to collect information on the demographic and socio-economic characteristics of the

Fig. 2. Categories of questions

respondents. This is essential for defining the representativeness of the survey sample, but also to understand how the sample of respondents, based on age, gender, ethnicity, and/or education level, relates to the topic. The literature [5] shows that the socio-demographic/economic data also makes it possible to identify trends or disparities between age groups or between different income brackets, to identify the main variables influencing the results of the questionnaire. Some examples could be: *what is your date of birth/ nationality/level of education?*. Similarly, some examples of questions related to the second category *property and income situation* are: *i) what is your employment situation? ii) if employed or studying, what kind of work do you do? iii) where is your place of work or study?*

The outcomes of the third and fourth categories of questions aim to collect data on the respondent's property and the characteristics of the context in which they live. The outcome of this category is for both studying trends in the real estate market and for characterizing the built environment. It is well known that a property is a composite good [10] and, in particular, its market value of a property is function of the quality of the neighborhood in which it is located and the characteristics of the property [11, 12].

Some examples of questions of these categories are: *i) what type of property do you live in? ii) how many rooms does your property have? iii) how far is the nearest public transport stop/park from your property?*.

As already explained, pollution resulting from the presence of industrial sites generally has a direct and significant impact on the welfare of the community. For this reason, the fifth category includes questions formulated using the CV method. The CV makes it possible to construct a hypothetical market to capture the community's WTP for reducing or eliminating the perceived risks associated with living near a polluting facility. In this sense, structuring questions to measure community WTP aims to understand how these areas affect the property market. In addition, WTP is a tool for decision-makers to assess the non-commercial value of resources and environmental improvements [13]. An example of a question with WTP in the fifth category is: *i) taking into account your household's income and expenditure, how much would you be willing to pay to clean up polluted areas in the urban context where you live?*

2.2 Phase 2: Analysis of the Main Sources

In order to specify how to structure each question to be included in the identified categories and collect useful data, it is necessary to carry out a targeted analysis of the official sources (such as standardized questionnaires used by the statistical institutes operating at the national level, i.e. in Italy ISTAT [14] and current regulatory provisions) and the reference literature.

The academic literature contains a large number of studies investigating how the presence of polluted sites affects the economic dynamics of a district and the real estate market. Pollution associated with the industrial facilities in urban areas strongly influences human health, leading some people to prefer cities with better air quality [15]. A large number of variables and econometric techniques have been used to examine the relationship between this typology of facilities and the property market mechanisms. Among the considered variables, are those describing the main features of the property [16], which can be divided into intrinsic variables (surface area of the dwelling, number of floors, presence of balconies and/or gardens) and extrinsic variables (proximity of the dwelling to green areas, etc.) are significant. According to them, the categories of questions related to the property intrinsic and extrinsic variables (i.e. data related to the house property and data related to the characteristics of the reference context) are investigated. Regarding the quantification modalities of these variables, there is a large body of researches that analyses the impact of the industrial sites on property values using the distance as a reference measure [17].

Particular attention is paid to the CV approach. In particular, in the literature on the topic, different Authors have assessed the WTP for an improvement in the level of well-being [18]. In this context, the last defined category of questions uses the WTP to evaluate the perceived risk associated with the proximity to the industrial site. For each of the five identified categories, following the analysis of the academic papers, targeted questions are structured to derive the necessary data to pursue the research objectives.

2.3 Phase 3: Definition of the Structure of the Questions

The third phase aims to define how questions will be structured to prepare the final questionnaire. The elaboration of the questions follows a two-stage approach. The first stage concerns an analysis of the relevant legal references and standardized questionnaires used by the main national and international public statistical authorities.

In Italy, the ISTAT provides statistical data, analyses, and forecasts in the social, environmental, and economic fields [14]. In particular, since 2018, ISTAT has implemented a questionnaire to collect the main characteristics of the Italian population. It includes a specific section on demographic information, education level and formation and occupational status. The questions in this ISTAT section correspond to the categories identified in the first phase of the proposed methodological approach, i.e. i) personal and social data and ii) patrimonial and income situation. In the same way, the ISTAT questionnaire includes a section on properties features, that includes the type of building, surface area, number of rooms, presence of lifts, availability of parking space, etc. These questions are useful to structure the question category iii) data related to the housing property.

Within the field of air pollution or environmental contamination, the SP methods are widely applied by researchers, by constituting a valid support tool to understand how the consumers evaluate a non-market good such as the environmental quality. In fact, in the reference literature, the administration of specific research questionnaires allows to analyze the residents' concerns about environmental pollution and to consider otherwise undetectable variables. For example, Guignet [19] examines how a sample of Maryland residents perceive the value of a property to be affected by an environmental nuisance such as a leaking storage tank (LUST) that exposes groundwater to high levels of pollution. The Author submits a questionnaire and the results show that the mere presence of a LUST in the urban area, without evidence of associated leakage or pollution, leads to a decrease in residents' WTP for property in the same area. Pignocchino et al. [6] design a questionnaire to analyze the correlation between the percentage of pollutants detected in an urban area and the perception and concern of the inhabitants. The study is based on a representative sample living in Italy and Sweden. The researchers attest the existence of the hypothesized correlation, and the questionnaire shows that the respondents' direct experience and the socio-demographic data influence their personal perceived risk of pollution. Similarly, Rahardyan et al. [20] develop a questionnaire to investigate the residents' attitudes towards solid waste management facilities. The research reveals that the main matters of the residents' regard the pollution and the health effects due to the presence of such facilities.

The information gathered from the analysis of the literature in this field allow to structure the questions in the fourth category. Further questions related to this category examine the relationship between the presence of polluted sites and the property market dynamics using the hedonic price method [21–23]. The hedonic price method studies the effect of some specific attributes on the property selling price [24]. In this context, the most commonly used variable is the distance of the industrial site from the property [25–28].

Starting to detected information, the questions are developed, taking into account the available Italian and European guidelines for the preparation of effective statistical surveys [29].

2.3.1 Contingent Valuation

The formulation of some specific questions concerns the use of CV method.

Environmental quality is an increasingly important consideration for users of the urban system, particularly in terms of residential choices [30]. The CV is a SP technique based on a questionnaire describing a hypothetical market in which the good under consideration can be exchanged. For example, the environmental damage caused by the pollution resulting from the activities of an industrial site involves a loss of well-being for the community, which suffers in terms of health. The monetary valuation is quantified in CV with the maximum WTP, i.e. the maximum amount that users of the urban area would be willing to pay to restore the quality that the natural resource had before it suffered environmental damage caused by the presence of the industrial site [31].

The monetary valuation is also carried out in terms of the Minimum Willingness to Accept (WTA), i.e. the minimum amount of money that the community is willing to accept to compensate for the well-being loss resulting from the environmental damage.

In the proposed methodological approach, these typologies of questions are formulated to measure the community's WTP both for the implementation of interventions aimed at restoring the environmental quality of polluted urban areas and for living in a healthier context not compromised by the presence of industrial sites.

These questions need to be developed in different steps to provide the respondent with all the necessary information. First, a detailed description of the environmental good and the damage to be assessed is required. Then, a scenario is constructed and illustrated, i.e. the hypothetical market. This is a rather complex operation, as a sufficiently plausible and comprehensible hypothetical market must be built so that respondents can assign valid values [32]. At this stage, the respondent is therefore asked questions to understand the value they would pay for the good if they were in a position to acquire it. Eliciting the respondent's WTP can be done in several ways: i) an open-ended question in which the respondent indicates the amount of money by stating their WTP; ii) a closed-ended question in which the respondent accepts or rejects a monetary amount defined in the question; iii) a question in which a range of values is proposed from which the respondent chooses; iv) two closed questions in which the interviewer proposes a second value (lower or higher, depending on the previous value proposed and rejected by the respondent); v) successive questions in which progressively higher or lower values are proposed to approach the value that the respondent identifies as closest to their WTP.

Concerning the present research, in the structured questionnaire there are questions aimed at measuring the respondent's WTP for property located in urban areas other than the one in which they live, to understand the reduction in perceived well-being associated with living in an urban area close to an industrial site. To do this, the monetary amounts used in the definition of these questions are taken from the databases of property quotations; for example, in the Italian context, every six months the Observatory of the Real Estate Market (OMI) of the Italian Revenue Agency [33] defines a minimum/maximum values range expressed in €/m^2. These amounts are intended to reflect both the ordinary selling prices and the rental value of the residential properties located in each homogeneous territorial area defined by the OMI. In line with the mentioned objective, the questions take into account the average property prices of the area in which the respondent lives and compare them with the property prices charged in the areas that have better urban quality.

3 Conclusion

The presence of industrial facilities in urban residential areas is a cause for concern because of the impact on human health caused by a deterioration in the environmental quality to which the community is exposed. This issue is particularly important for the cities that have industrial plants, as the personal perception of risk by users of the urban system leads them to make different housing choices.

This paper aimed to define a methodological approach for structuring a research questionnaire focused on the analysis of the effects of the presence of polluted sites on the communities' perceptions. The questionnaire represents a survey tool used to collect data on the opinions, attitudes, and experiences of a sample of individuals and it is used to examine quantitative and/or qualitative information for expressing the SP of the individuals.

Within the present work, the structuring of the questionnaire has been functional to pursue two main objectives: i) to investigate the existing relationship between the presence of the industrial sites responsible for pollution and the dynamics of the real estate market; ii) to collect data directly from the community that can be used by decision-makers in the development of interventions to be implemented in the territory.

The implementation of the structured questionnaire in this research has been a valuable tool to support the analysis of the community's perception of the risk associated with the presence of an industrial site in a residential area. This perception makes it possible to estimate the value that users of the urban system attach to the possible loss of well-being in polluted areas. Among the advantages, the proposed questionnaire fills the gaps that can be observed in the implementation of regression models. These models, unlike a questionnaire, do not allow us to capture the perception of the subjects. However, among the disadvantages there is the difficulty related to the subjectivity of the respondents that, often, may overestimate or underestimate the actual amount of money they would be willing to pay.

Future developments of the proposed methodology include applying the questionnaire to a sample of people living in an urban area where an industrial plant is located. An example is the city of Taranto, which is home to one of the largest steel plants in Europe - Acciaierie d'Italia s.p.A (formerly ILVA). This industrial plant has caused the environmental degradation of the surrounding urban area, with the gradual abandonment of many residential properties. The data provided by the questionnaire administration could support the definition of strategic policies to be implemented for the effective regeneration of the Italian city in question [34–39].

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An Artificial Neural Network Based Model for Urban Residential Property Price Forecasting

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Abstract. The predictive accuracy of Machine Learning (ML) and Artificial Intelligence (AI) models has increasingly encouraged their application in the pro-perty evaluation studies and, more generally, in the economic research.

While the predictive potential of these models is now widely acknowledged, they have often been criticised for being likened to 'black boxes' that yield results that are difficult to interpret. In this regard, thanks to some recent advances in the field of eXplainable Artificial Intellicence (XAI), there is a growing debate on the need to use explainability techniques to make the predictions of ML models easier to interpret and, consequently, more reliable.

This paper aims at a twofold objective. Firstly, it intends to investigate the importance of explainability models for a transparent analysis of the predictions returned by ML and AI. Secondly, it proposes a novel and automated methodological approach that integrates Artificial Neural Network (ANN) with a Geographic Information System (GIS). The use of GIS has the advantage of geo-localising on a map both the input data, i.e. the intrinsic and extrinsic characteristics of each property, and the results of the model, expressed in terms of expected prices. In addition, the method-logical approach envisages the use of an Explainer Model (EM) that allows for a transparent interpretation of the ANN results, making it possible to read the contribution of each variable to the expected price. In summary, the methodology thus defined is able to provide planners and decision-makers with a completer and more reliable picture of real estate trends. Case study applications will test the proposed ANN-GIS approach.

Keywords: Forecasting housing prices · Machine Learning techniques · Artificial Neural Networks · Geographic Information System

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1 Introduction

Estimating dwellings values accurately and reliably is a matter of extreme interest for real estate stakeholders [1]. According to Rico-Juan and de La Paz [2], due to the macroeconomic importance of house price developments, forecasting dwellings values becomes crucial for both buyers and real estate companies. By predicting market trends, on the one hand, buyers can plan investments in advance, saving time and purchase costs. On the other hand, real estate companies can also adopt marketing strategies to maximise the benefits [3]. In addition, providing forecasts of property values is also crucial for a fair valuation of properties for tax purposes [4], as well as to help planners understand market trends after the implementation of land use policies [5–7].

A significant controversy emerges in the literature between those who favour the use of conventional models based on hedonic techniques and those who demonstrate the high potential of Maching Learning (ML) techniques in real estate [8].

The hedonic model is the one most widely used in housing economics to estimate the willingness to pay for each property characteristic. It, in fact, makes it possible to estimate «differentiated goods like housing units whose individual features do not have observable market prices» [9]. Therefore, the shadow prices of the dwelling characteristics are estimated using a conventional hedonic model in which each component reveals the bidders' preferences for each characteristic [2].

The ML-oriented approach, like the hedonic model, relates real estate characteristics (input) to the variable to be predicted, i.e. the house price (output). However, for the prediction of the output it makes use of different families of algorithms that are in turn capable of learning both linear and non-linear relationships. With the developments in data engineering in multiple sectors of the economy, a new debate is emerging on the potential of machine learning techniques, which some scholars believe can provide better forecasts than econometric methodologies, even if they are not based on socio-economic behavioural models. According to Rico-Juan and de La Paz [2], while it is true that ML techniques ignore the laws of economics and the explanatory models that show causality, they are nevertheless able to identify non-linear relationships between variables that - from an economic perspective - would reflect the behaviour of agents interacting in the market.

Data analysts claim that another potential of ML-oriented approaches is the ability to accurately predict socio-economic variables using large datasets. In this regard, mention should be made of the well-known mass valuation technique, a system that combines several machine learning tools to assess house prices based on a large dataset of surveyed observations [10]. ML techniques, when employed for mass appraisal (MA), have even greater potential when integrated with Geographic Information System (GIS). In fact, as Liu et al. point out [11] «GIS with its large database technology, super computer graphic processing and spatial analysis capability, provides a comprehensive and accurate information technology platform for real estate appraisal industry». Instead, the main criticism levelled by economists is that ML techniques function as 'black boxes' that return spurious results that are often difficult to interpret [12, 13]. However, recent major advances in the explainability of ML models make them increasingly interesting, with important consequences for their interpretability, robustness and, ultimately, reliability [14].

This paper first demonstrates the necessity of employing explainability approaches for the correct interpretation of property value forecasts using ML techniques. It then defines an innovative methodological approach that integrates Artificial Neural Network (ANN) with a geographical information system, emphasising its potential usefulness for decision-makers and property investors and, more generally, in the field of economic research.

2 State of Research

For decades, hedonic models have formed the basis for empirically assessing real estate prices based on their intrinsic and extrinsic characteristics. The Hass hedonic price model [15], also known as multiple regression analysis (MRA), has been the main forecasting method in real estate so far. However, some authors point out that multicollinearity between characteristic variables in outlier samples can seriously impair performance [16]. Other scholars argue that MRA may generate biased or underestimated forecasts, especially when data models show non-linearity [17, 18]. Therefore, Machine Learning (ML) algorithms have been proposed as possible solutions to handle linear and non-linear relationships in a dataset where both categorical and numerical variables exist. According to Watson [19], supervised ML can be defined as «the typical supervised learning setup involves a matrix of features X (predictors, independent variables, etc.) and a vector of outcomes Y (the response, dependent variable, etc.) that together form some fixed but unknown joint distribution P (X, Y). The goal is to infer a function f that predicts Y based on X. A model f is judged by its ability to generalize, i.e., to successfully predict outcomes on data that were not included in its training set».

Some of the most tried and tested ML algorithms include: (i) k-Nearest Neighbours, also known as KNN or k-NN, is a non-parametric supervised learning classifier that uses proximity to make classifications or predictions about the clustering of a single data point. This model interpolates the final predictions based on the 'neighbours' proximity according to the Euclidean distance [20]; (ii) Decision Tree (DT) that predicts the value of a sample by learning simple decision rules, hierarchically [21]; (iii) Random Forest (RF) that builds multiple decision trees to combine all the predictions for more robust behaviour [22]; (iv) Artificial Neural Network (ANN), a model that replicates the human brain's learning process. It consists of a network of interconnected nodes, called artificial neurons, that process input information and generate an output [23].

Most of the studies on the use of ML to predict property prices have focused mainly on the predictive performance of the algorithms, while less attention has been given to the explainability of these models. In fact, there are still few studies on ML that analyse the contribution of individual input variables to property price prediction [24–26]. Two main types of eXplainable Artificial Intelligence (XAI) approaches emerge from the literature: global and local. The former, of which Permutation Feature Importance (PFI) is a part, refer to the trained model. The logic is to perform permutations on the value of each input variable and compare the variability in the predictions.

Local Interpretable Model-Agnostic Explanations (LIME) and SHapley Additive exPlanations (SHAP) are emerging among the local explainability approaches, which also allow us to understand which characteristic variables contribute most to the prediction. For each input sample to be explained, the LIME generates new samples of similar data. The model is re-trained and the LIME configures the differences between the predictions generated from the original data samples and those generated randomly [27, 28]. The idea behind the SHAP approach is to see what happens in the model when a feature is missing. This avoids re-training the complex model without generating new values for the feature of interest [29].

3 Methodology

The paper aims to characterise an automated and innovative methodological approach for property price forecasting, based on the joint use of Artificial Neural Networks (ANN) and Geographic Information System (GIS). Among the ML techniques, the artificial neural network is chosen because the algorithms on which it is based, even if they are more difficult to interpret than those of other ML models, tend to achieve the best results [2]. The greater difficulty in interpreting the results, however, is overcome by combining the Machine Learning Model with an Explainer Model (EM) that allows a more transparent reading of the predictions returned by ANN. Finally, the ANN-GIS integration allows the geolocation on a map of both the input data - intrinsic characteristics, extrinsic characteristics, and property prices - and the results of the model, expressed in terms of predicted prices.

The logical-operational steps on which the model is based are described below.

1. **GIS data collection.** With reference to the study area, data is collected on property prices, their intrinsic characteristics and zonal or neighbourhood attributes, understood as social, economic, and environmental characteristics [30–32]. All this information is mapped and managed in a GIS environment.
2. **Artificial Neural Network Design and implementation.** Before setting up the network, we briefly describe how it works. The latter is based on the interaction of neurons. The interconnected neurons function by receiving commands from the 'dendrites' (connectors). They then process information, which is transmitted by the 'axons' (connectors) to another neuron [33]. The operation of the ANN is triggered by an activating function that integrates the input values. This information is then transferred from the input layer to a hidden layer. At the hidden layer, a double operation takes place: (i) the weighted sum by which all inputs are added together multiplied by their respective weights; (ii) the transfer of the weights to the transformation function, from where the output is produced. The transformation function, which determines the relationship between input and output, can be: linear, linear threshold, step linear and sigmoid [34]. Figure 1 schematises the operation of ANN.

Phase 2 is divided into the following sub-steps.

2.a. Definition of network architecture. A preliminary step is the normalisation of the input data, which are dimensionally different from each other. In fact, normalisation is the process by which all input data are brought to the intervals [0,1]. If normalisation is not performed, the input data will have an additional effect on the neuron, leading to wrong decisions. Then the network architecture is defined. There are three main architectures, namely: recurrent network, single-layer feed-forward network and multilayer feed-forward network [36]. However, in real estate evaluations the most widely used is the Back-Propagation artificial network (BP network) that is a multi-layer feed-forward neural network, which consists of input layer, hidden layer and output layer. The input variables are represented by property attributes.

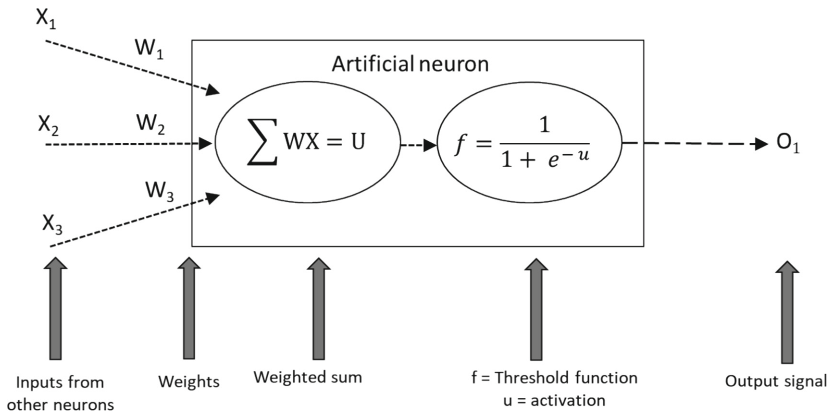

Fig. 1. Operation diagram of the ANN. Source: Adopted from Wong et al. [35]

The hidden layer is the intermediate layer between input and output where the mathematical processing takes place. Simplifying, a hidden layer is a set of neurons with specific activation function, whose task is to process input from previous layers to extract specific features. The number of these layers depends on the complexity of the problem to be solved, but properly calibrated as more hidden neurons does not result in more accurate results.

It follows that before training the network, the decision maker must specify: the number of neurons n_i in the input layer, which corresponds to the number of real estate features; the number of neurons n_o in the output layer. Since the output is the price of real estate, we have that $n_o = 1$; the number of hidden layers and the number of neurons n_h in each of these layers. Although it is difficult to establish univocally n_h, Ward [37] suggests the following expression to determine the number of neurons in the hidden layer:

$$n_h = \frac{n_o + n_i}{2} + \sqrt{N_s} \tag{1}$$

With N_s, the number of training samples. The literature does not stipulate the number of samples required to build an ANN model. According to some authors, a small data sample is sufficient and does not need more data than is normally required by linear models to perform excellently [38]. Mora-Esperanza [33], on the other hand, argues that the number of samples should be proportional to the number of variables.

2.b. Setting of network training parameters. This phase results in (i) setting the initial weights and choosing the activation function; (ii) determining the training time; (iii) selecting the expected error for training networking; (iv) choosing the BP network promotion algorithm. The setting of the network's initial weights (i) has a great influence on the training time, network convergence and local minimum. Equally significant is the choice of the activation function: the sigmoid remains the most widely used as it is easily applied in computer programming [1].

The normalised dataset is then randomly divided into three different samples: typically, 70 per cent is used as the training set of the network and the remaining data is equally divided between validation set, to measure the generalisation of the network, and testing set, to assess the performance of the network during and after training. The definition of training time (ii) is crucial, as «if the network is overtrained (over fitting), it will affect the generalization ability of the network, that is, after training, the network will make the error response to the sample that is out of the scope of training» [11]. In the network training process, the expected error (iii) is a value that is accepted when, after numerous comparisons and trainings, it is sufficiently small. This error decreases with increasing training time and the number of neurons in the hidden layer. An error of 0.001 is usually selected for network training.

The most widely used BP network promotion algorithm is the Levenberg-Marquardt (L-M) algorithm, which provides a numerical solution to non-linear least squares problems. This is a combination-type algorithm of gradient descent method and the quasi-Newton method.

2.c. Implementation of the model. Once the network training parameters are defined, the network is trained to then return property price forecasts.

3. **Linear regression setting-up and implementation.**

By setting up a conventional hedonic model, it is possible to analyse the marginal contribution of each property characteristic - intrinsic and extrinsic:

$$\mathrm{Y} = \mathrm{X} \cdot \beta + \varepsilon \tag{2}$$

In (3), Y is a vector (n $\times$ 1) of individual house prices, generally specified in logarithmic terms; X is a matrix (n $\times$ k) of independent variables, generally represented by property characteristics (intrinsic and extrinsic); β is the vector of k coefficients to be estimated; ε is a vector (n $\times$ 1) of independent and identically distributed errors. Once the model has been calibrated and implemented, the assumptions on which the multiple regression is based must be verified [39–41].

4. **Metrics estimation and interpretation of results.** The metrics used to assess the goodness of the models are based on the measurement of errors:

$$\mathrm{RMSE}(y, \hat{y}) = \sqrt{\frac{1}{n}\sum \left(y_i - \hat{y}_i\right)^2} \tag{3}$$

$$\%\mathrm{RMSE}(y, \hat{y}) = \frac{\sqrt{\frac{1}{n}\sum \left(y_i - \hat{y}_i\right)^2}}{|\bar{y}|} \tag{4}$$

$$\mathrm{MAE}(y, \hat{y}) = \frac{1}{n}\sum \left|y_i - \hat{y}_i\right|^2 \tag{5}$$

$$\%\mathrm{MAE}(y, \hat{y}) = \frac{\frac{1}{n}\sum \left|y_i - \hat{y}_i\right|^2}{\left|\bar{y}_i\right|} \tag{6}$$

$$P(y, \hat{y}) = \frac{\sum 1\left|\frac{y_i - \hat{y}_i}{y_i}\right|}{|y_i|} \tag{7}$$

$$R^2(y, \hat{y}) = 1 - \frac{\sum (y_i - \hat{y}_i)^2}{\sum (y_i - \overline{y})^2} \tag{8}$$

In which: RMSE is the root mean square error; %RMSE is a percentage of RMSE compared to the mean of true values; MAE is the mean absolute error; %MAE is the percentage of MAE compared to the mean of true values; P is the degree of explanatory accuracy of the model; R^2 is an index of determination to assess the acceptability of the results; y and $\hat{y}$ are the vectors with true and predicted values, respectively.

To interpret the ANN results transparently, an explainer m©ecent advances in the literature, the SHapley Additive exPlanations (SHAP) is used to explain ANN predictions, a tool that links game theory and local or global explanations by combining different methods [42]. The SHAP technique helps the analyst to understand the contribution of all selected features to the final evaluation and their mutual relationships. The main idea of the SHAP approach is to see what happens in the model when a feature is missing. This avoids re-training the complex model without generating new values for the feature of interest, and without losing the real-world reality [43].

5. **Mapping the results in GIS environment.** Once the models have been implemented and the results validated, they are entered into GIS mapping. In this way, for each property in the study area, it is possible to visualize both the input data and the result expressed in terms of predicted prices with the two different models: the ANN and the RLM.

Figure 2 schematises the proposed methodological approach.

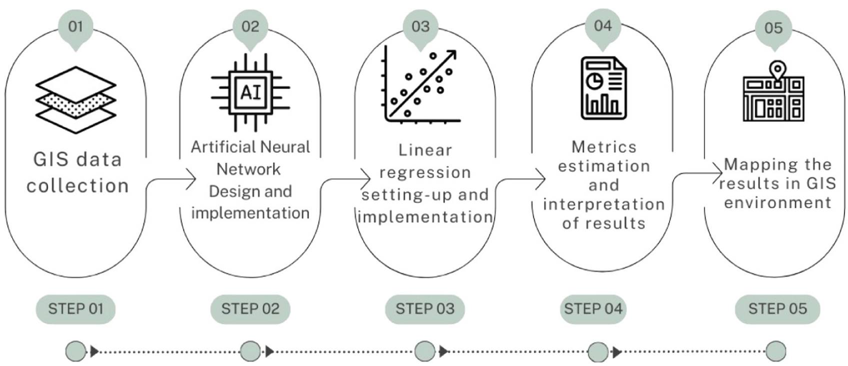

Fig. 2. Outline of the prediction methodological approach.

4 Conclusions and Future Perspectives

The forecasting of urban property values is an extremely important issue not only for potential property buyers, investors, tax assessors, insurance companies, but also for governments [1]. However, it is critical for several reasons: firstly, because of the complexity of the real estate market, an atypical and highly dynamic sector; secondly, because the forecasting judgement is significantly influenced by the choice of interpretation model [44].

In this regard, the literature shows a significant controversy between those who favour the use of conventional models based on hedonistic techniques and those who demonstrate the predictive capabilities of Machine Learning (ML) techniques. While the potential of these techniques is recognised, they have often been criticised as being black boxes that return results that are difficult to interpret. It is only thanks to recent advances in the field of eXplainable Artificial Intellicence (XAI) that ML methods are becoming increasingly attractive and robust.

This paper, after investigating the importance of explainability models for a correct interpretation of predictions conducted with ML techniques, proposes an innovative methodological approach that integrates Artificial Neural Network (ANN) with a Geographic Information System (GIS). The ANN-GIS integration allows both input data and model results to be automatically geolocalised on a map. On the other hand, the difficulty of interpreting the ANN results is overcome by associating the ML model with an Explainer Model (EM) based on the SHAP technique that allows the contribution of each variable to the expected price to be read. It is a five-step methodology: (1) GIS data collection; (2) Artificial Neural Network Design and implementation; (3) Linear regression setting-up and implementation; (4) metrics estimation and interpretation of results; (5) mapping the results in GIS environment. The methodology thus defined may therefore represent a useful support tool for decision-makers in urban spatial planning processes.

Future research developments may concern, first, applications to case studies to test the ANN-GIS approach. In addition, the methodology can be extended to other AI and ML algorithms specifically defined for the interpretation and prediction of real estate markets.

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Rebuilding the Metropolitan Cities' Suburbs via Co-creative Sustainable Initiatives: Supporting Framework for Efficient Public-Resources Policies

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Abstract. Public housing estates in major European cities, mostly built in the second half of the 20th century, today face challenges related to housing, urban decay, socio-economic depression, and marginalization. However, these neighborhoods, which have similar characteristics in all European suburbs, represent a valuable resource in the context of sustainable development principles that promote reuse. This work aims to define a methodological approach aimed at identifying intervention strategies, protocols, and sustainability indices that can be replicated in regeneration interventions in these neighborhoods. This approach involves a comprehensive analysis of existing housing, residents' needs, and innovative regeneration strategies, developing a methodology for evaluating urban regeneration interventions. The proposed approach includes the definition of a model for sustainability assessment, experimental implementation, and validation in real case studies. The research aims to contribute to the identification of replicable and adaptable strategies for social, economic, and environmentally sustainable urban regeneration, highlighting stakeholder involvement.

Keywords: Sub-urban areas · housing market · integrated framework

1 Introduction

The suburbs of major European cities are often characterized by extensive social housing estates built mainly in the second half of the 20th century. Originally created to meet the high demand for housing among low-income families, these neighbourhoods are now experiencing housing and urban decay. They are often socioeconomically depressed and marginalized areas in close proximity to urban centers [1].

These neighbourhoods, spread across several European cities, share common critical issues such as "segregation" and the socio-spatial concentration of disadvantaged people and ethnic minorities. This concentration often leads to social problems such as

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marginalization, vandalism, and stigmatization of residents [2]. Even greater challenges arise from the physical characteristics of these neighbourhoods, which are characterized by low-quality buildings with structural, maintenance, and energy efficiency problems that negatively affect the quality of life of residents. In fact, these neighbourhoods have specific characteristics due to a series of choices resulting from the context and the period in which they were built. The choice of materials and construction methods, which have made this heritage prematurely obsolete, have been significantly influenced by the standards, technologies, and financial constraints of the period in which these neighbourhoods were developed [3]. A common feature of these neighbourhoods, for example, is the construction of buildings using prefabricated building systems to meet the sudden demand for housing in a short period of time [4]. While prefabrication has allowed for rapid and efficient construction, it has also posed long-term challenges related to the quality and type of materials used and the need for frequent maintenance. In addition, today it involves a not easy transformation of the size and articulation of housing, which is often necessary due to the changing composition of households and the different ways in which the interior spaces of housing are used.

Despite their critical issues, the neighbourhoods, which have similar characteristics throughout European suburbs, represent significant public assets and a valuable resource in the context of sustainable development principles that promote reuse [5]. Indeed, choosing to reuse existing structures saves resources such as materials, energy, and land, while modifying the environmental impacts associated with new construction. It also optimizes financial resources by taking advantage of the cost-effectiveness that characterizes the reuse of structures over the cost of demolishing old buildings and constructing new ones [6]. These neighbourhoods often host established communities, so the preservation and rehabilitation of these neighbourhoods play a central role in promoting social sustainability [7].

In fact, in contemporary models of urban transformation, the regeneration of public housing neighbourhoods is emerging as a key strategy, evident in the formulation of sustainable development policies [8]. Among these, the New European Bauhaus, introduced by the European Commission, seeks to integrate sustainability, affordability, and accessibility in the design and renovation of buildings, with a focus on promoting the adaptive reuse of buildings, with an emphasis on affordable housing solutions [9]. This alignment with broader international goals is evident in initiatives related to the Sustainable Development Goals (SDGs) outlined in the 2030 Agenda [10]. In particular, in Goal 11, "Sustainable Cities and Communities", where special attention is given to interventions aimed at transforming and restoring areas in decline [11], including through interventions structured to take into account the environmental impacts achieved by incorporating Nature-Based Solutions (NBS) into the project [12]. The sustainability of urban regeneration practices is critical to advancing the SDGs, ensuring a balance between urban development and social-environmental well-being. Integrating SDG principles into these practices can significantly improve the resilience, inclusivity, and community focus of cities [13]. To fill the gaps and improve the overall quality of life in these areas, it is necessary not only to improve the energy and environmental performance of the buildings and urban spaces in these neighbourhoods but also to activate urban forest systems and new social and economic functions that produce ecosystem services [14].

Intervention strategies in these urban areas therefore require an integrated approach, taking into account not only architectural and urban planning aspects, but also social, economic, environmental, and cultural aspects, as well as the real needs of users [1]. To identify and verify the target of the general and specific objectives to be achieved in the redevelopment of each of these neighbourhoods, indicators of social and environmental economic sustainability are used at different scales (urban, building, etc.), but they are often not considered in a joint and integrated manner [15].

The study aims to create a framework for flexible revitalization tactics in public and affordable housing neighbourhoods on the outskirts of major European cities from the 1970s to the 1990s. It proposes a methodological approach to identify sustainability indices, protocols, and strategies for supporting neighbourhood-level redevelopment. This replicable approach targets areas with similar socio-economic contexts, offering scalable solutions for urban regeneration challenges. The approach-building takes into account the characteristics of the housing stock, the needs of the tenants, and innovative revival strategies used in similar community situations. By establishing indicator-sets that effectively reflect the complexity of phenomena linking urban dynamics to the ecological, social, economic, and architectural elements of the territorial context of reference, this is accomplished with proficiency. As previously mentioned, Sect. 2 covers some of the instruments for evaluating urban sustainability at multiple analysis-scale; Sect. 3 describes the phases of the suggested methodological approach. The findings are covered in Sect. 4.

2 Tools and Frameworks for Comprehensive Urban Sustainability Assessment

Given the complexity of issues related to neighbourhood regeneration interventions, a comprehensive understanding of how to intervene requires consideration of the multiple aspects of urban sustainability [16].

The need to integrate sustainability principles into design and planning practices has led to the diffusion and development of various frameworks and tools for assessing urban sustainability at different scales [17, 18]. These tools provide a structured approach to defining and measuring sustainability, promoting a holistic view of urban development and regeneration initiatives in accordance with social, economic and environmental sustainability criteria dictated by international agendas [19, 20]. This approach must take into account the interconnectedness of the economic, social and environmental dimensions and the interrelationship between the different scales, thus contributing to a more comprehensive and integrated understanding of sustainability [21].

In general, urban sustainability assessment tools are based on indicator systems that measure different aspects of sustainability and allow the comparison of neighbourhood performance against predefined criteria [22]. These tools have been developed at different scales, from the individual building scale to the national scale, to the neighbourhood scale, to the city scale, emphasizing the importance of a holistic approach to assessment [23]. Each level of analysis focuses on different aspects relevant to the issue under consideration. For example, at the building level, there are several tools (BREEAM, LEED, CASBEE, etc.) where the assessment focuses primarily on aspects related to the performance of the individual building [24]. These include aspects such as resource use and efficiency, energy and water conservation, waste management, and indoor environmental quality [25]. Many tools originally designed to measure sustainability at the individual building level have evolved to address challenges at the neighbourhood level (such as BREEAM Com, LEED for Neighbourhood Development, and CASBEE for Urban Development) [26]. This evolution underscores the need for larger-scale assessments that allow for a more balanced consideration of environmental, economic, and social aspects than individual building assessments [17]. Indeed, at the neighbourhood level, a number of interrelated issues emerge, including the organization of elements within the neighbourhood, the arrangement of green spaces and commercial areas, as well as factors such as transportation accessibility, the presence of economic assets, and energy consumption patterns [27].

Evaluating all these aspects requires a multidisciplinary approach that can take these factors into account simultaneously; among evaluation tools, multicriteria techniques are well suited to this type of assessment [28]. In fact, compared to other types of approaches that only allow for the evaluation of the convenience and feasibility of interventions in monetary terms (techno-economic feasibility analysis, cost volume profit analysis, cost-benefit analysis, etc.), multi-criteria analyses allow for the consideration of a plurality of aspects of different nature). Multicriteria analyses can be used both to evaluate the sustainability of urban renewal initiatives according to different categories, taking into account different criteria and indicators, and to identify the preferences of the stakeholders involved in such initiatives [29]. After defining the specific objectives of the operations to be evaluated, these analyses involve defining the criteria to be used for the evaluation, which may include economic, social, environmental, and cultural aspects, and the indicators that represent them [30]. Multicriteria analyses involve stakeholders in the decision-making process by asking them to provide subjective assessments of the different criteria to be adopted and their relevance [31]. In fact, these assessments are used to determine the different criteria in different situations or contexts and, consequently, the weights to be assigned to the indicators, which, being representative of the different criteria, are weighted according to the stakeholders' interests.

3 Methodology

Given the diverse range of evaluation techniques and instruments to be employed in the context of sustainability accounting across urban neighbour regeneration processes, the goal of the current contribution is to develop a comprehensive concrete route that may serve as a kind of guide for the renovation of urban public assets with the previously mentioned qualities. Taking into consideration the socio-economic spatial arrangement that distinguishes European megacities and drives the development of the sub-urban region where consistent housing assets found site, the goal was to incorporate both practical and thorough insights into the protocol's formulation.

The proposed methodological approach includes three phases, namely (i) state-of-the-art analysis, (ii) problem setting, and (iii) experimentation and synthesis (see Fig. 1). Each of these phases involves a series of activities, which are explained in the following paragraphs.

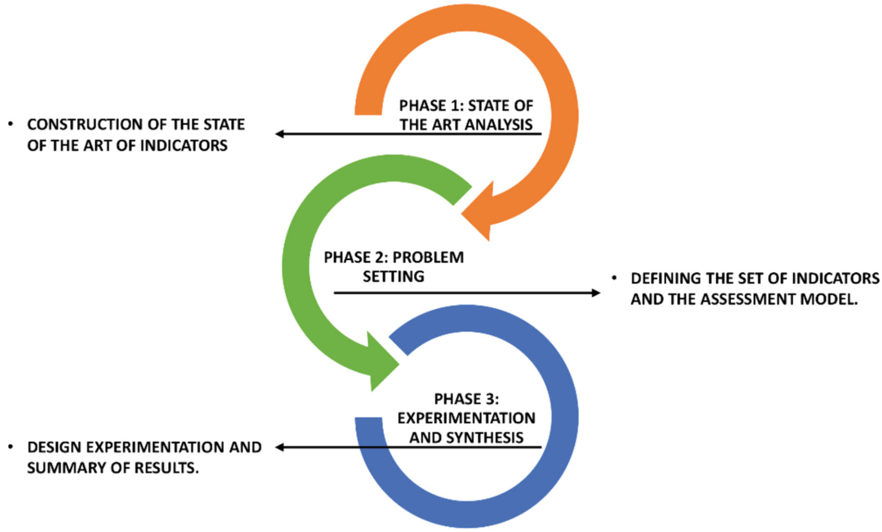

Fig. 1. Three-stage protocol of analysis

3.1 Phase 1: State of the Art Analysis

The proposed methodological approach involves a comprehensive study to identify indicators for assessing the viability and sustainability of interventions in public housing neighborhoods at both the building and urban scale. Through in-depth research, a preliminary set of indicators related to social, environmental, and economic aspects of urban/architectural sustainability will be established.

In order to measure sustainability, this in-depth research seeks to: (i) define a comprehensive set of indicators, (ii) systematize their collection, and (iii) identify critical factors for selecting appropriate indicators. The approach integrates both *bottom-up* and *top-down* approaches, which involve exploring real-world best practices and conducting a systematic review of scientific articles on sustainability indicators in urban environments.

***Bottom-up* approach.** This process begins with the approach of a real case representative of the redevelopment actions put in place, of which information inherent to the *ex-ante* and *ex-post* state of the intervention is available. This in order to understand its distinctive characteristics, criteria, and sustainability indicators adopted and adoptable to measure its effectiveness and environmental, social, and economic-financial sustainability.

Specifically, starting from a study of working-class neighbourhoods built in major European cities in the 1970s-1990s, which allowed:

- an understanding of their urban, technological, typological, and social characteristics,
- a mapping of the critical issues, contents, and distribution of these neighbourhoods in the cities under study,
- the identification of the most innovative regeneration strategies implemented,

- the selection of best practices related to regeneration interventions based on parameters and evaluation criteria.

The *Cité du Lignon* in *Vernier*, Geneva, Switzerland, was selected by a panel of experts as a representative case study. Built between 1964 and 1966, it underwent extensive renovation in several phases from 2017 to 2021 and was included in the Federal Inventory of Swiss Settlements to be Protected (ISOS) in 2021. Although it occupies only 8 percent of the district's 28 hectares, its tall buildings, amenities, green spaces and preserved forest heritage along the *Rhone* and *Nant des Grebattes* have had a significant impact on biodiversity and social life. The methodology involves a study of the information related to the case study to identify: key-variables, type of variable, unit of measurement, source of calculation, and category of sustainability.

Top-down approach. In this process, the proposed methodology involves a systematic review of national and international literature to identify key indicators used to assess sustainability in urban environments.

The main steps of the systematic review are:

1. definition of the main topics to be investigated by formulating the research questions in accordance with the study's goals.
2. selection of databases and, consequently, the choice of keywords to be used in the literature search.
3. selection of exclusion criteria to find research articles in line with the objectives of the study.
4. collection of the following information: sustainability categories, related variables/indicators, and techniques, mode of measurement of indicators, unit of measurement of indicators, spatial scale of indicators, whether the indicators are sustainability services or disservices through the further analysis of the chosen articles, the sources from which relevant data for the indicator's definition can be obtained.

The simultaneous application of both approaches and an initial comparison of the results allows for mutual validation, ensuring that the information derived from the specific case is consistent with the more general findings of the literature review. In order to substantiate the validity and general applicability of the proposed indicators, questionnaires are administered to professionals, including construction and real estate technicians and practitioners, as well as environmental and social experts. This validation process will make it possible to assess the clarity, sufficiency, and acceptance of the proposed indicators, which will be crucial for the implementation of the next protocol stages.

3.2 Phase 2: Problem Setting

Defining an evaluation model to measure the sustainability of regeneration interventions is the proposed activity for this phase. Based on the primary indicators that have been determined for evaluating urban sustainability performance at different scales and in line with the primary categories of analysis that represent the primary goals to be pursued by the various stakeholders engaged in the interest area's revitalization process, the building model will be established.

Owing to the greater flexibility of multi-criteria logics in assessment frameworks related to the revival of urban public housing assets, the following fundamental guidelines are appropriate to adhere to while building a sustainable evaluation model through the use of indicator sets:

- correlation analysis between the chosen indicators to make sure each one is present and to disperse the indicator that is overly useless;
- normalizing the values of the single indicators that were thought to be the analysis's drivers would result in a common scale of values and a standardized framework that will guarantee the model's consistency and uniformity;
- weighting procedure, taking into account the various priorities of the stakeholders participating in the various regeneration operations, in order to represent the relative value of each indicator.

The aforementioned three principles serve as the foundation upon which operators may build resilient and flexible models that enable them to execute a variety of decision-making processes in light of the specific sustainable goals (environmental, social, and economic) that must be achieved.

3.3 Phase 3: Experimentation and Synthesis

The methodological approach culminates in an experimental testing of a regeneration intervention plan that is derived from one or more case studies. Testing the suggested strategies and identifying potential regulatory obstacles to redevelopment initiatives in line with cutting-edge European redevelopment methodology are the two main goals of the experimentation.

Quantitative survey phase. During this phase, a quantitative survey will be carried out to determine the true quality of housing demand in the target neighbourhoods. This will be done by analyzing the technological and typological shortcomings found in the current housing patrimony, which will include both individual homes and buildings, as well as public spaces. To ascertain the present housing demand and the wants of the locals, including prospective new inhabitants in the research region, a particular survey is included in this step.

Development of solutions. By use of a questionnaire and interactive exercises, a framework that can interpret the requirements, issues, and anticipations of the concerned parties may be constructed. This survey serves as the foundation for developing focused solutions that deal with the particular issues facing the neighbourhoods. The specific problem may be seen in connection with the interval evaluation operation of the intervention (pre-, during-, and post-intervention), particularly when employing an indicator set that can facilitate the assessment procedure under a co-participatory philosophy of action.

Use of indicators. The defined indicators will be applied:

- *ex-ante*: to confirm current state before regeneration measures.
- during implementation: to continuously monitor the compliance of the intervention with the strategy and to adapt to new problems.
- post-intervention: to verify the results and evaluate the success of the remediation programs.

Through this practical experiment, an overview is obtained that provides qualitative and quantitative data to assess the compatibility of the intervention with the housing stock and public space.

4 Conclusions

This work aims to address the challenges associated with public housing estates built between the 1970s and 1990s in the suburbs of major European cities.

The objective is to define a methodological approach aimed at identifying intervention strategies and tools for assessing the sustainability of regeneration interventions in these neighbourhoods. The proposed approach will be developed in three phases. The first consists of a state of the art analysis that provides an overview of the characteristics of these neighbourhoods and identifies best practices for regeneration. The integration of bottom-up and top-down approaches in the definition of sustainability indicators is crucial to ensure a complete and accurate assessment of the performance of regeneration interventions.

The second, problem setting phase, based on quantitative and qualitative surveys, helps to understand the existing deficiencies in the neighbourhoods and to identify the specific needs of the residents. This approach makes it possible to take into account architectural, urban, social, economic, and environmental aspects, ensuring targeted and participatory solutions.

The proposed methodological approach ends with a design experimentation phase in which regeneration strategies are tested and validated through the application of *ex-ante*, in-progress, and post-intervention indicators. This process provides qualitative and quantitative data to assess the impact of regeneration initiatives on the quality of life and sustainability of the urban areas involved.

The proposed methodological approach is replicable and adaptable in similar contexts, promoting social, economic, and environmental sustainability. In this context, the importance of involving local stakeholders, understanding community needs, and adopting an integrated perspective emerge as key elements in the formulation of successful regeneration strategies. Future research will involve applying the proposed methodology to different urban areas with similar characteristics. This will assess the robustness, effectiveness, and replicability of the approach in different urban settings, contributing to a stronger knowledge base for future regeneration interventions.

Note. This contribution has been developed within the current research "Post-COVID future cities. Methods and tools to design and assess, healthy, sustainable and resilient suburbs", Call for Research Projects 2021, Sapienza University of Rome.

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From Eco-Industrial Park to Eco-Agricultural Park in the Peri-Urban Context: A Proposal

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Abstract. With the growing environmental concern, there is evidence that increasing the symbiotic relationship between companies in the same industrial area highly contributes to the more sustainable development of industrial activities. These principles inspired the concept of Eco-Industrial Park (EIP). A lot of EIP examples and realisations already exist throughout the world, and a lot of Eco-Industrial Park proposals are in progress achieved through different methods that can support the creation of exchange networks in these Parks before their design and construction. The scientific community can consider the symbiotic relationship of Eco-Industrial Parks in the Peri-Urban context. The application of the principles of industrial symbiosis in the agricultural sector is an important and, above all, necessary change to transform society, face future challenges, and become more resilient to crises. However, this change requires innovative business models that must make use of the broad involvement of all actors in the agricultural supply chain. Therefore, the work aims to would highlight how the principles of Eco-Industrial Parks can favour the realisation of Eco-Agricultural Parks through sustainable and innovative practices, initiatives, and performances in the Peri-Urban context. An additional objective is to analyse the implementation of symbiotic relationships starting at a Dairy Farm in a South Italian Region, in order to the potential benefits to in-house production areas, neighbouring companies, and the local community through the Eco-Agricultural Park in the Peri-Urban context.

Keywords: Symbiotic Relationship · Peri-Urban Context · Environment · Eco-Agricultural Park · Italy

1 Introduction

In recent years, the interest in industrial areas, production systems, and the territory in which they are located managed according to the principles of the sustainability paradigm [1].

In fact, the growing attention on *i)* the environmental sustainability of raw materials, products, and production processes; *ii)* the expansion of markets in a global dimension; *iii)* the growing desire of consumers to buy in the short term; *iv)* the effects of

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climate change on territorial balance and human health because pollution phenomena; *v)* the importance of using criteria of social equity in the distribution of wealth and the protection of human rights; led to the transformation of the current global supplying, production and distribution system [2–4].

In the Declaration of Toledo (2010) the European Ministers for regional development, in the light of the principles of sustainability, defined the territory as "a complex system, comprising not only urbanised, rural and other spaces, e.g. industrial land, but nature as a whole and the environment surrounding mankind" [5], so it is necessary to adopt a holistic multidisciplinary approach capable of harmonising the various variables, economic, environmental and social sustainability local. While, a production system can be understood as the total composite of many elements – interdependent and of a different nature – that have the common goal of realising the transformation of input resources into finished products as output. This definition of the production system fits into a larger context which is the industrial area defined as the territory in which they are located to achieve economies of scale due to common services and infrastructure [5, 6].

Internationally, this translates into the concept of Eco-Industrial Parks (EIPs), within which are established mutually beneficial symbiotic relationships between organizations and their environment, through the management of raw materials, by-products, and waste shared [7].

The idea of Eco-Industrial Parks was first described during a presentation at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. It was intended to bring together producers of commodities and services to improve their economic performance and at the same time protect the environment by managing natural resources collectively [8]. Residents of EIPs uphold high standards of energy efficiency and engineering solutions and work together to ensure that the waste of one company provides material for another while processed material is used to manufacture the end product. One of the most accepted definitions of EIP is that given by Lowe and Moran in 1995, for which the Eco-Industrial Parks can be understood as "a community of manufacturing and service businesses located together on common property. Member businesses seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues. By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual benefits each company would realise by only optimising its performance" [9].

By early 2005, communities in Africa, Asia, Europe, South America, and the United States had initiated EIP or other eco-industrial development planning processes. Nowadays, such EIPs are successfully developing in such countries as Canada (Hinton); the USA (Reventure Park); Denmark (Kalundborg); Finland (Rantasalmi); China (Dailan, Suzhou, Nanhai); Indonesia (Semarang, Industri Sona Maris); Japan; India; Vietnam; Thailand and Mexico [10]. Then, implementing Eco-Industrial Parks means not only improving the environmental performance of each enterprise but, rather, the strategic objectives of single-unit production match with those of other units belonging to the same area. This implies a greater availability of enterprises to cooperate with the other actors, both public and private, in the area to improve the management of the local community [11]. The creating synergy between companies through joint management processes and/or exchange of raw materials and energy can lead to economies of scale, an increase in the potential for innovation, the reduction of environmental impacts, and an increase in its competitive utility. The principles underlying Eco-Industrial Parks represent the framework from which to hypothesise that it is possible to apply the same principles in the agricultural sector by considering the symbiotic relationships that, starting from a Dairy Farm, can bring benefits to the internal farm production areas, neighbouring farms and the local community through the recovery of waste from livestock farming and transformation processes that, integrated into other production processes, can be considered resources, in a system where the principles of sustainability are pursued [12]. Thus, the Eco-Agricultural Parks (EAPs) will be discussed.

From this background, this paper aims to would highlight how the principles of Eco-Industrial Parks can favour the realisation of Eco-Agricultural Parks through sustainable and innovative practices, initiatives, and performances in the Peri-Urban context. An additional objective is to analyse the implementation of symbiotic relationships starting from a Dairy Farm in a South Italian Region, in order to the potential benefits to in-house production areas, neighbouring companies, and the local community through the Eco-Agricultural Park in the Peri-Urban context. The paper is organized as follows. The next section describes the theoretical background. The proposed Eco-Agricultural Park is later reported and a discussion section. A conclusion section ends the paper.

2 Theoretical Background

2.1 Eco-Industrial Parks Model

The EIPs model can be considered an appropriate framework for the implementation of an Eco-Agricultural Park. The EIPs make it possible to address many aspects such as *i)* resource efficient and cleaner production; *ii)* energy efficiency; *iii)* industrial symbiosis; *iv)* climate change; *v)* pollution; *vi)* social standards; *vii)* shared infrastructure; *ix)* improved spatial zoning and management [13].

According to Lowe's definition (1997) [14], there are different types of EIPs: *i)* Eco-Industrial Parks or Estates, parks developed and managed by a single entity to obtain high economic, and social benefits environmental expertise; *ii)* By-product Exchange, groups of organizations aimed at the implementation of the symbiotic relationships, which promote the exchange of waste to reduce resource consumption and pollution; *iii)* Eco-Industrial networks, understood as groups of enterprises located in the same territory and oriented to the satisfaction of all the principles of sustainability to improve the economic, social and environmental performance of all players present the same territory. In this paper, it will consider the By-product Exchange type. The focus will be on the symbiotic relationships between the Dairy Farm and other enterprises aimed at recovering waste from milk production to be transformed into resources for other enterprises in or near the Park in the Peri-Urban context.

Support for the development of EAPs can be offered through the provision of an economically, environmentally, and socially integrated approach and an appropriate development plan to meet the sustainability paradigm principles in a Peri-Urban context. In particular, it is possible to identify key environmental, economic, and social drivers of Eco-Agricultural Parks (Table 1) starting with that used for the realisation of EIPs [13].

Table 1. Main key drivers of EAPs.

Economic	Environmental	Social
– Direct and indirect employment creation;	– Climate change commitments at the global and national levels;	– Better working and labor conditions;
– Skills-upgrading of the labor force;	– Increased demand to improve efficiency and growth;	– Provision of vocational training;
– Technology and knowledge transfer through foreign direct investment;	– Responding to environmental and social concerns from consumers	– Improved occupational health and safety;
	– Ensuring infrastructure is resilient to higher resource costs and adapts to climate change risks;	– Creation of green and digital jobs;
– Management of material and immaterial resources and conservation;	– Greening the supply chain and alleviating resource constraints;	– Transition to more sustainable land use;
		– Provision of social infrastructure to workers and community;
– Linkages between operational centers of the Park, small and medium-sized enterprises (SMEs) and communities outside the EAP;	– Presence of relevant legislative mechanisms;	– Support to local communities' well-being;
		– Provision of social infrastructure to workers, community and territory;

Reaching these targets requires deep and long-lasting changes by organisations that will participate in the realisation of an Eco-Agricultural Park in the Peri-Urban context.

2.2 International and National Dairy Production

The global market continues to be characterised by strong upward tensions due to the reduced availability of dairy products. World milk production is decreasing in all major exporting countries, due to rising costs and unfavourable weather conditions, which have impacted farmers' management choices despite a milk price being positioned at historically high levels.

In recent years at the European level[1], drought and high summer temperatures negatively impacted both pasture availability and maize yields and farmers found themselves having to supplement cattle rations with those that they would normally have stored for

[1] All data in this section are taken from the ISMEA 2022 Report. Available on: https://www.ismeamercati.it/flex/cm/pages/ServeAttachment.php/L/IT/D/1%252F0%252F1%252FD.6e69136bd2376c2cc40f/P/BLOB%3AID%3D12325/E/pdf?mode=download.

the winter. Despite the summer heat, the drop in milk production was most noticeable in the spring months and, in the first seven months of 2022, European Union (EU) milk deliveries were down 0.5% overall compared to the previous year. The drop in production affected some of the main producing countries (-1.3% in Germany and France, -1.9% in Spain) while, in others, after accelerating over the previous two years, there was a setback (Italy -0.2%, Ireland -0.8%). The exception was Poland, where – thanks to the good performance of pastureland – production continues to increase (+2.4% in January–July 2022).

Cow's milk production in Italy has increased significantly over the last five years, exceeding 12.6 million tonnes in 2020 (+13.4% compared to 2015, +4.4% between 2020 and 2019).

As deliveries have increased (+13% over the last five years), the farm gate price of domestic milk increased on average by 3% between 2015 and 2020. Over the last ten years in Italy, the incidence of small farms (with less than 50 head of cattle) has decreased from 61% to 53%, to the advantage of the larger size classes. In particular, the weight of large farms (100–500 head of cattle) has increased and they now account for more than one-quarter of the total and raise more than half of the total number of head of cattle. At present, about 80% of dairy cattle are kept on holdings larger than 100 head of cattle. Over the next five years, the estimated increase in cattle milk production in Italy is 10–15%, with an average annual rate of change of about 2–3%. Imports are expected to decrease (by an estimated -8% in volume between 2020 and 2025), taking into account the increased availability of domestic raw materials and the decrease in domestic demand. Exports, by contrast, are expected to increase significantly (by an estimated +25% in volume between 2020 and 2025), taking into account the growth prospects of global demand supported by the increase in global population and income and development levels in 'emerging' areas. At present, national milk covers over 80% of domestic needs. Considering the estimated growth rates of national cow's milk production, Italy could reach (or almost reach) self-sufficiency in raw materials in 2025.

Whereas the strong heterogeneity of the profitability of Italian livestock breeders, the livestock farms most likely to survive in the medium to long term will be those that are larger, more structured, with a generational change, better organised, and more inclined to make investments in technology and genetics.

An increase in cow's milk production at the national level is assumed for the next five years. In particular, Italy should align itself with the growth trend of world production rather than with that of Europe, with an annual increase of 1.6%, compared to the + 0.6% forecast for Europe. The increase in production stems from the breeders' quest for competitiveness; producing greater quantities means spreading fixed costs and thus benefiting from economies of scale. A part of Dairy Farms is economically sustainable, being equipped with high technical and managerial know-how and with strong incentives to increase production. Less structured farms will manage to continue their activities, but within specific niches or in the presence of substantial resources to support social sustainability, aimed at enhancing the territory and its products and at avoiding the depopulation of certain areas.

The profitability of the national milk supply chain is influenced by the global dairy market. Milk production will therefore tend to stabilise, also due to the influence of exogenous factors, such as the introduction of new environmental regulations, the prices of production inputs, competition with other producers within the EU, and the consequent compression of milk prices. Furthermore, the Italian production system is very feed-intensive, which leads to a position of dependence on the input markets (e.g. maize and soya) and the relative international dynamics. In the medium term the availability of land, a non-repeatable factor, will also be a limiting variable for production. These criticalities could be solved through the dissemination of Eco-Agricultural Parks.

3 Eco-Agricultural Park in a Peri-Urban Context: A Proposal

This section will present a proposal for an Eco-Agricultural Park starting from to Dairy Farm, Sele Milk Srl[2], that mainly produces the *Mozzarella di Bufala Campana DOP*[3].

The Sele Milk Srl was founded in the early 1900s and is one of the oldest manufacturing companies in the Sele Plain, near the Temples of Paestum, a UNESCO heritage site, in the Campania region of southern Italy.

The fertile land and mild climate have created a natural habitat for grazing buffaloes, whose milk has favoured the production of the *Mozzarella di Bufala Campana*, which was awarded the *DOP* brand name in June 1996.

The EAP area covers 200 hectares of land, including cultivated land and stables for housing animals directly connected to the milking parlour, which is equipped with a carrousel system that allows the milking operation to be carried out quickly but carefully. There is also a refrigeration area. The Dairy Farm represents the center of the EAP proposed (see Fig. 1), where several productive organisations can be included. Closely connected to it are, in particular, the packaging company and the biogas plant.

The EAP's main activity is, therefore, the production of *Mozzarella di Bufala Campana DOP* from the milk of buffaloes that grow in an environment where animal welfare is guaranteed. Nutritional requirements are met by fodder grown in an area of the EAP specifically dedicated to its production.

In particular, the buffaloes breeding produces high-quality milk that is destined for the Sele Milk Srl in the area of EAP, which processes it into a typical and certified product, that is *Mozzarella di Bufala Campana DOP*. The Sele Milk Srl, for its main production, releases polluting waste into the environment that can be recovered. The systemisation of by-products contributes to reducing environmental pressure, ensures an improvement in the use of energy resources, and reduces operating costs. For this purpose, the main by-products of the Dairy Farm can be exploited by the other production organisations of the EAP.

[2] For privacy reasons, the name of the company is not mentioned in this paper. A artificial name will be used.

[3] Since 1981, the Consortium for the Protection of *Mozzarella di Bufala Campana DOP* has been working to support and promote *Mozzarella di Bufala Campana* in Italy and around the world. Through to the work of the Consortium, the *Mozzarella di Bufala Campana* obtained the Protected Designation of Origin (*DOP* in Italian acronym) in 1996. The prestigious European brand name institutionally recognises the unique organoleptic and product characteristics of this cheese, which are the result of the special environmental conditions and traditional processing methods adopted in the specific production area.

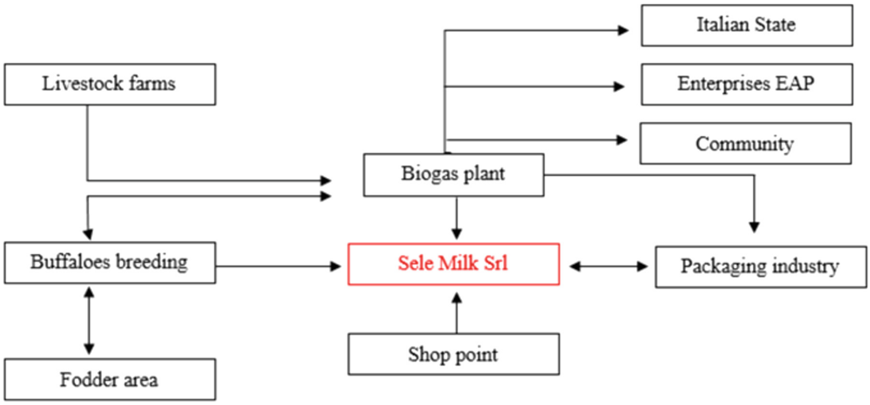

Fig. 1. Proposed representation of Eco-Agricultural Park starting to Dairy Farm in a Peri-Urban context.

This is the case with whey permeate, the main waste product of milk processing, which becomes a resource in the production of mozzarella packaging. In line with the By-product Exchange approach, Sele Milk Srl decided to offer sustainable packaging for its flagship product, the *Mozzarella di Bufala Campana DOP*. The packaging of choice is a bio-polymeric whey protein coating. Purifying the whey yields film-forming proteins suitable for processing and use as a raw material for the creation of highly recyclable and eco-friendly organic plastic. The whey protein-based polymer barrier can replace petroleum-based plastics and can be removed using enzymes for recycling. In addition, the material has better barrier properties than existing polymers. The shelf life of the products is maintained, and the sensory characteristics are better than if a conventional film were used; the maintenance of food safety regulations in terms of volatile compound emissions is guaranteed.

While the fodder needed to feed the animals can be produced in a cultivation area of EAP and wastewater from buffaloes breeding can be used to fertilise these fields. Instead, the remaining wastewater can be used for biogas production. In fact, in the EAP area is present a biogas production plant through anaerobic fermentation is in operation; the slurry produced is collected through the grid system that makes up the floor of the stables, pumped into a digester, and mixed with other biomass. This makes it possible to produce electricity and fertilise the land with the residue in a natural and environmentally friendly way.

In order to feed the biogas plant, neighbouring rural farms deliver their livestock residue to the plant to reduce disposal costs and ensure a local symbiotic mentality.

The bioenergy produced from waste meets Sele Milk Srl's energy needs and, in parallel, is sold to the Italian State or other organisations present in the EAP area, to meet the energy needs of the area, the community, or the territory of reference.

By adopting the Eco-Agricultural Park model, the need for material resources can be met by the output of the various operational centers that make up the area.

Therefore, by following a holistic cradle-to-cradle environmental approach, the management of waste from mozzarella production provides sustainable packaging solutions, waste reduction, recyclability of certain materials, and the production of new resources to be reintroduced into the production cycles of the same company or those of other companies in the EAP [15].

4 Results and Discussion

The Sele Milk Srl company considered employing a differentiation strategy by offering products with tangible and intangible elements that increase their absolute value for the target market of reference.

The principal product is given the characteristics of uniqueness, value, perception, and economic sustainability.

However, the company decided to operate responsibly and transparently towards people, communities, and the environment and manifests a willingness to prioritise the implementation of the sustainability paradigm in the Peri-Urban context. The reputation and value system are the company's intangible assets, which are perceived by customers.

With a view to differentiation within the *Mozzarella di Bufala Campana DOP* supply chain, the most important and decisive step is certainly the promotion of a circular economy based on the exploitation of waste products and their reuse after treatment through the implementation of EAP [16]. The logic behind EAP responds perfectly to the circular economy model and the needs of sustainable consumers, a category that has grown more since the Covid-19 pandemic in the 2020–2022 period. In Italy, for example, 30% of shoppers say they avoid buying plastic products; 36% have stopped buying products because of the negative impact on the environment; 62% prefer to buy from companies that show concern for the environment [17].

The Sele Milk Srl company, sharing your by-products and the production waste with the other operational centers of EAP, fully fulfils the circular economy model and is among the companies that are potentially preferred by the new category of consumers.

The management of a complex system of activities like EAP needs coordination that is fundamental to the functioning of each operation center, wherein resources can be the waste product of another activity in the same or other chain. It is, therefore, necessary for the organisation of EAP to be led by someone with good leadership skills.

In addition, the EAP management starting at Dairy Farm requires a good capacity of investment and know-how. Also, in the light of the fact that milk has the highest production costs in Italy as compared to the main EU producers that achieve similar quality performance.

Therefore, Agro-Eco Park products must be able to appeal to a broad user base that guarantees a good return in the Peri-Urban context.

Unfortunately, the consumption trend of milk-derived products is slowing down throughout the Western world, which is showing eating habits increasingly oriented toward plant-based products, also supported by heavy marketing investments.

The significant increase in the global population will remain the main driver of demand growth, although consumption patterns and expected trends may vary from country to country and in step with income and development levels. Italian Dairy Farms are oriented towards specialities [18]. Producers in the DOP segment will have to continue to produce at high-quality levels in order to support and confirm the Made in Italy image on world markets and benefit from the increased added value. Considering current consumer needs, there is a need for coordinated information and communication strategies that:

– highlight the supply chain's commitment to environmental, social and nutritional sustainability;
– counter the negative social perception by consumers of intensive livestock farming.

The environmental issues cannot be solved by reverting to the past, but through the introduction of appropriate technologies and innovations, adequately supported by research.

In fact, the evocation of bucolic agriculture, still much promoted in the media, is no longer realistic. Environmental and social sustainability and food security are achieved only through technological innovation, advances in genetics, improvements in animal nutrition, valorisation of waste, and sharing of by-products and energy [19].

Structuring the supply chain with a view to environmental and social sustainability and animal welfare will increasingly be strategies adopted by those organisations oriented towards the creation of shared value in the medium and long term. An important contribution in this sense could be given by the establishment and diffusion of EAPs which certainly support the creation of the sustainability paradigm in the Peri-Urban context.

5 Conclusions

In the current context of resource scarcity, global climate change, environmental degradation, and increasing food demand, the implementation of EAPs represents a promising strategy for making the agri-food sector sustainable, restorative, and regenerative.

Knowing that the natural resources of the world are limited, solutions have to be found to decouple economic growth from resource consumption. For this reason, it is necessary to adopt tools, standards, models, and procedures of environmental and social sustainability, shared both by public players and private ones present in the territory, to address enterprises towards a real redevelopment path for the creation of a sustainable territory system, in particular, in the Peri-Urban context. Enterprises, consumers, but also citizens, are called to interpret, in different ways, global sustainability challenges, and implement concrete and distinctive actions, taking the opportunities offered by greater attention to environmental and social aspects management. In the agri-food sector, one way to address these challenges could be the implementation of EAPs based on the circular economy model and symbiotic relationships. This is the case of the Sele Milk Srl company located in the Peri-Urban context and at the center of EAP described in this paper.

This is characterised by the *Mozzarella di Bufala Campana DOP* production. From buffaloes, milk is produced, which, when processed, gives rise to *Mozzarella di Bufala Campana DOP* and whey permeate. The latter can be used for the production of sustainable packaging in order to preserve and transport the mozzarella. From the recovery of the by-products, it produced energy through the biogas plant.

Such production is part of a system that respects nature and the consumer, which is realised through symbiotic relationships that favour the exchange of waste and the valorisation of waste into resources, in order to reduce resource consumption and negative economic, environmental, and social externalities.

Therefore, it will be important to pursue the logic that governs an EAP to satisfy the needs of consumers who are increasingly oriented towards purchasing products made using sustainable processes and to respond to global sustainability challenges also in the Peri-Urban context.

The conclusions extracted from this conceptual study offer some important practical implications and directions for future research. Thus, practitioners could use these findings to develop a specific system that favours the realisation of Eco-Agricultural Parks in the Peri-Urban context.

Furthermore, this research could also have implications for policymakers, who can stimulate, through specific legislation, transparency of information and better the diffusion and implementation of Eco-Agricultural Parks.

Future research will focus on the evaluation of EAPs' impacts on the economic, environmental, and social sustainability of enterprises, communities, and citizens of reference in the Peri-Urbano context.

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Neighbourhood Markets as Driving Force of Suburbs' Urban Regeneration: The Case of the City of Rome (Italy)

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Abstract. Neighbourhood markets are essential elements within urban areas, with particular relevance in peripheral areas lacking services and gathering places. These markets, considered as public spaces and social architectures, offer significant potential for urban regeneration and social evolution. This study examines the economic and financial aspects of municipal local market regeneration projects, with a specific focus on a peripheral district of the city of Rome (Italy). Socio-economic investigations are utilized to structure a comprehensive framework for assessing project feasibility, with a particular emphasis on public entities as the primary investors. The returns from these endeavours go beyond mere financial gains, encompassing a broad range of considerations, including environmental and social impacts.

Keywords: Neighborhood Market · Urban Regeneration · Social Impacts

1 Introduction

Neighbourhood markets, commerce, and the places where such activities take place are fundamental factors for the development of cities. The history of neighbourhood markets is closely intertwined with that of urban areas, influencing their evolution and transformations, and contributing to the definition of public spaces, which serve as venues for social interaction, goods exchange, and community gathering [1].

In the ancient Greece, the neighbourhood market was symbolized by the *agora*, the central square of the *polis*, where trades took place, citizens' assemblies convened, interpersonal relationships were forged and maintained, and major public buildings were situated. Currently, the concept of public spaces has evolved into a connective element

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among large private consumption centres, while traditional markets have progressively lost their appeal [2].

The city of Rome (Italy) has a long-standing tradition of public markets, playing a pivotal role in shaping the urban landscape for many centuries. Within the city's territory, seventy neighbourhood markets are distributed in a heterogeneous manner, primarily characterized by fixed stalls. Among these, 44% fall under the category of "covered" markets, while the remaining are "open-air" markets. On average, each market hosts 77 stalls, with a minimum of 11 stalls observed at the market district named "Conca d'Oro", and a maximum of 247 stalls at the "Trionfale" market, resulting in a total of 2,554 stalls throughout.

However, the neighbourhood markets of the city of Rome currently display a clear decline, marked by challenging survival prospects and reduced commercial appeal. This is evident through a substantial average vacancy rate equal to 21.93%. Among the occupied stalls, the majority (typically around 60%) are dedicated to activities related to the food sector [3]. Hence, for the revitalization and requalification of neighbourhood markets, it is imperative to conceive them as laboratories for experimentation and mediation among diverse interests. In this way, local markets can assume a fundamental role in supporting processes of economic and social recovery in the urban areas they serve [4, 5]. The requalification can also benefit from the application of "Bauhaus" principles, a globally recognized architectural model that, following the footsteps of the Industrial Revolution and the Modernist Movement, harmonizes the aesthetic value of an object with its technical and functional components [6]. As an extension of the premises of the European Green Deal [7, 8], the New European Bauhaus is designed to address climate change, pollution, and biodiversity loss, making sustainability more tangible by incorporating these realities into the design of high-quality living spaces for European citizens [9]. Furthermore, the presence of neighbourhood markets has been shown to have a positive impact on social and environmental quality. Therefore, it is important to carefully consider economic sustainability, which is constantly under review. However, the implementation of renovation interventions aimed at optimizing accessibility and the effectiveness of services within neighbourhood markets raises the question of the financial feasibility of such actions.

2 Aim

The present study aims to analyse the economic and financial aspects related to the regeneration projects of four municipal neighbourhood markets in the periphery of the city of Rome. These interventions are conceived as "deep" renovations involving demolition and reconstruction of the existing market structures, with the goal of improving the accessibility of the offered services. It is imperative to underline that the assessed interventions are deemed necessary, regardless of the current maintenance state, in line with the programmatic guidelines established for the City Government in the five-year period 2016–2021, as approved by Municipal Resolution No. 9 of August 3rd, 2016. This resolution included the objective of revitalizing local markets, a significant portion of which currently finds itself in a state of severe degradation and abandonment [3].

The work is structured as follows. In Sect. 3, the intervention area is defined, encompassing an examination of the context, social aspects, and the trends in the real estate market. Section 4 outlines the economic and financial feasibility of the projects by analysing the specific revenues and costs. In Sect. 5, the conclusions are examined and discussed.

3 Framing of the Intervention Area

3.1 Context

The IX municipality is located in the southern area of the city of Rome and covers an approximate area of 183.2 km^2 with a population density of around one thousand inhabitants per km^2. The municipality is divided into thirteen urban planning zones and exhibits an extremely diverse urban structure, encompassing both highly populated and well-defined areas (e.g., the EUR district, Spinaceto), as well as territories resembling the Roman countryside (e.g., Vallerano). Additionally, within the municipal territory, there are two natural reserves (Decima-Malafede and Laurentino-Acqua Acetosa) that occupy a significant portion of the macro-area under consideration.

3.2 Social Aspects

The markets under study are situated in four different neighbourhoods (Vigna Murata, Spinaceto, Laurentino, and Tor de' Cenci), which are adjacent to each other. These neighbourhoods share limited socio-economic heterogeneity. Demographic analysis reveals that three neighbourhoods (Spinaceto, Laurentino, and Tor de' Cenci) have high population densities, with approximately 4,500 inhabitants per km^2, whereas the Vigna Murata neighbourhood has a lower population density. This exception also extends to the percentage of foreign residents in relation to the total population, which is over 25% for Vigna Murata and under 10% for the other three neighbourhoods. Regarding the age distribution of the population, the study confirms the "barrel" structure that has characterized the national demographic pyramid in recent years. The predominant age group falls between 45 and 55 years, with the Laurentino neighbourhood showing a higher proportion of individuals between 55 and 64 years of age [10]**.** The unemployment rate is relatively low across the four neighbourhoods, averaging about 7.8%.

The area associated with the Vigna Murata market stands out with a higher per capita income (28,014 €), nearly double that of the territorial areas related to the Spinaceto and Tor de' Cenci markets (15,143 €). The Laurentino neighbourhood falls in an intermediate income position. This income gap is also reflected in the consumption propensity, which is more pronounced in Vigna Murata (4,087.43 €) compared to the areas related to the Spinaceto and Tor de' Cenci markets (3,267.16 €).

However, the data for the employment rate (the ratio of people in the labour force to the corresponding reference population) is relatively homogeneous, standing just above 50%**.**

3.3 Real Estate Market

The areas where the studied complexes are located, in reference to the categories defined by the Real Estate Market Observatory (OMI) of the Italian Revenue Agency, fall into the "peripheral" macrozone for the Vigna Murata market and the "suburban" macrozone for the other three local markets. The Spinaceto and Tor de' Cenci markets belong to the same OMI zone.

Vigna Murata - Via Andrea Meldola. Based on information obtained from the OMI database in the commercial sector, the first half of 2022 saw a slight increase in average prices, stabilizing in the second half of 2022. This trend solidified the reversal of the trend that occurred in the second half of 2021 after more than five years of continuous decline. Rental rates over the past seven years have exhibited a fluctuating pattern, with a significant downward peak in the first half of 2020 that continued until the second half of 2021 when, in line with sales prices, an increase was recorded. For the area where the Vigna Murata market is located, in the second half of 2022, the average market value is 1,675.00 €/m^2, and the average annual market rent is 11.8 €/m^2 per month.

Laurentino - Via Francesco Sapori. In contrast to the previous situation, the area associated with the Laurentino market has shown a generally decreasing trend since 2015, both in terms of sales and rental prices. Unlike sales prices, which deteriorated further in 2021, rental rates appear to have stabilized at their current level since the first half of 2020. For the area where the Laurentino market is situated, in the second half of 2022, the average market value is 1,375.00 €/m^2, and the average annual market rent is 11.5 €/m^2 per month.

Spinaceto - Viale caduti della Resistenza / Tor de' Cenci - Via Renzo Bertani. The area related to the Spinaceto and Tor de' Cenci markets has exhibited a generally decreasing trend since 2015, both in terms of sales and rental prices. However, since the first half of 2020, there has been a stabilization of the average values for both sales and rents. For the area where the Spinaceto and Tor de' Cenci markets are located, in the second half of 2022, the average market value is 1,300.00 €/m^2, and the average annual market rent is 9.9 €/m^2 per month.

4 Economic and Financial Feasibility of the Intervention

To provide an overall view of the medium to long-term impacts of the redevelopment project, financial analyses have been carried out using the Discounted Cash Flow Analysis (DCFA). This approach method aims to assess the sustainability of each intervention. The application of DCFA requires the preliminary identification of revenue and cost items that contribute to determining the feasibility of the operation, along with certain assumptions regarding the analysis period and the discount rates used in the evaluation. The analysis period is assumed to be twenty years, following the common practice of an ordinary investor who, after a reasonable period of operation profitability, tends to divest the asset under evaluation. Moreover, according to specific requirements of the Public Administration (that is the owner of the four neighborhood markets), a public-private partnership hypothesis (i.e. "project financing" mechanism) has been further proposed for the Spinaceto district market, in order to assess the potential convenience to choose this management modality.

4.1 Revenues

The Legislative Decree 114/1998 defines a “market” as a public or private area for which the Municipality has jurisdiction, composed of multiple stalls, whether equipped or not, and intended for carrying out commercial activities on one or more days of the week or month, providing an integrated offering of retail goods, serving food and beverages, and providing public services. A similar definition has been subsequently adopted in the Regional Law of Lazio No. 22 of November 6, 2019, also known as the Unified Trade Text.

As of January 1st, 2021, the Law No. 160 of 2019, in Article 1, paragraphs 837 and following, established that occupancies within markets, even those without infrastructure, are regulated through the payment of a conventional fee, referred to as the “market fee.“ This fee replaces the payment for the use of public spaces and areas (COSAP) for tenants, which is still applicable for isolated stalls outside of the market, rotations, kiosks, newsstands, and, more generally, for occupations outside the market site. Furthermore, fixed-site local markets within the territory of the municipality of Rome have the option to establish a self-management committee, which can result in a reduction of the fee payable to the Public Administration, ranging from 20% to 50% of the regular quota [11].

Authorization for the operation of selling activities in public areas through the use of a stall in covered and equipped markets, and the related concession of the stall, are issued to both individuals and legal entities by the relevant municipality, in accordance with the provisions set out in the Assembly Capitolina Resolution No. 108 of September 10th, 2020.

Additionally, markets fall under the category of so-called “public services on an individual demand” as defined by the Ministerial Decree of December 31st, 1983. For these types of services, municipalities are annually required to approve the respective tariffs for individual services and the percentage with which these fees cover total costs. To calculate the revenues generated from market management, the “market fee” provided for in the municipal regulation has been considered, assuming the absence of a self-management committee. Therefore, the assumed fee is 74.00 €/m^2 per year, applied to the commercial area of each stall (averaging approximately 25 m^2). Total revenues begin from the second year of the analysis period since the first year is “committed” to project implementation. It is assumed that lease fees are annually updated based on the ISTAT index, using a variable and decreasing inflation rate (6% in the third year of the analysis, 3.5% from the fourth to the tenth year, and 2% for subsequent years, as a target value in the EURO area in the medium to long term). Revenues also include the terminal value of the investment, estimated as the construction costs of the entire structure and discounted to the twentieth year. Table 1 summarizes the total revenues for each local market in the second year and the terminal value in the twentieth year.

It is also evident that the overall benefits of the project will be manifold. Once implemented, these projects can act as a catalyst for initiating additional and subsequent redevelopment initiatives in the surrounding territorial context, triggering long-term virtuous processes of urban regeneration. Furthermore, the projects include the installation of a photovoltaic system on the markets, financed by third-party entities, resulting in a

Table 1. Summary of revenues.

Market	Revenues at year 2 [€]	Residual value at year 20 [€]
Laurentino	83,250	4,355,092
Spinaceto	116,550	4,545,063
Tor de' Cenci	88,800	4,332,611
Vigna Murata	140,304	5,075,543

reduction in CO2 emissions, as well as the energy self-sustainability of the structures and, where sufficient, a financial surplus from the sale of energy.

4.2 Costs

The assessment of the overall project cost has been carried out regardless of the current maintenance conditions of the markets, taking into account the proposed interventions necessary to enhance the utilization of the offered services, ensure a higher standard of energy performance, and trigger positive social spillovers in terms of community well-being within the relevant context.

The costs of the interventions are assessed by applying economic items derived from the use of official reference price lists to the characteristic quantities of the project's work categories. When official reference price lists are not available, market surveys are carried out, supported by price analysis. Due to the level of project development associated with this analysis, the cost calculation is performed in a summarized manner, by considering the primary functions outlined in the project for which appropriate and objective construction costs of a parametric nature have been identified. This cost encompasses the sum of expenses incurred for the production of the work categories related to a specific unit of measurement.

The construction costs of the project are assessed by considering the following main work categories to be carried out:

– Demolition of the existing market.
– Construction of stalls and facilities.
– Walkways.
– Roof covering for the market.
– External area improvements.

For each work category, an appropriate parametric cost has been determined. Unit costs have been updated chronologically based on ISTAT revaluation coefficients for construction costs and by work category. Based on the estimated parametric costs, the total construction costs of the four interventions have been determined (Table 2).

Starting from the construction costs, the indirect costs (e.g. insurance, property management, maintenance expenses, technical fees, etc.) have been determined, i.e. additional expenditure items that contribute to defining the production cost of each intervention (Tables 3). In particular: the insurance is assumed as an annual cost, equal to

Table 2. Construction costs for each district market under study.

Market	Surface [m^2]	Construction costs [€]	Unit cost [€/m^2]
Laurentino	3,831.50	2,930,851.83	764.94
Spinaceto	4,150.00	3,058,697.07	737.04
Tor de' Cenci	3,787.50	2,915,723.12	769.83
Vigna Murata	4,453.00	3,415,695.02	767.05

0.10% of the construction costs of the initiative; the property management is an annual expense, equal to 1.00% of the annual rent; the maintenance expenses (annual) are equal to 0.50% of the construction costs; the technical fees are assumed equal to 10% of the construction costs, and they are paid *una tantum*.

Table 3. Summary of the markets' production costs.

Market	Production costs [€]
Laurentino	4,050,467
Spinaceto	4,227,150
Tor de' Cenci	4,029,559
Vigna Murata	4,720,525

As regards to the discount rate to be applied in the DCFA, it should be highlighted that it appreciates the specific risk of the operation (as well as the trend of macroeconomic and financial variables), and therefore differs from case to case, in relation to the nature, location, size, etc. of the real estate investment under consideration. In particular, two components must be considered for the determination of the discount rate: *i)* the return of an alternative risk-free investment (typically assumed to be equal to the average yield of Treasury bonds with a homogeneous duration compared to the reference analysis period of the initiatives) and *ii)* the remuneration of the risk of the operation itself (i.e. the "premium" linked to the possibility that the investor does not receive the expected flow at the scheduled date).

In the specific case, for each neighborhood market, the investor is represented by a public entity, for which the "returns" of the operation will be related not only to the revenues that can be translated into monetary terms, but also to the effects - environmental, social, etc. - that the initiatives will generate in the territorial context of reference for the local communities. Therefore, a "risk-free" rate, aligned with the average yield of Italian Treasury bonds at the date of this analysis (= 3%) has been considered as the discount rate of the cash flows.

4.3 Discounted Cash Flow Analysis

The developments of the DCFA for the four markets under analysis are reported in Table 4. The results show that for the Vigna Murata and the Spinaceto neighborhood markets, the Net Present Value (NPV) of the investment is higher than zero, whereas it is negative for the Laurentino and Tor de' Cenci markets. However, when analysed collectively - as a unique investment of urban redevelopment of the macro-area in analysis -, the total delta is very low, compared to the social and environmental benefits generated by the projects in the medium-long term. In particular, in order to achieve the economic balance of the investment in the four markets being evaluated, it is sufficient to consider an annual and constant economic benefit - in terms of raising the level of social and environmental quality - equal to 15,000 €.

Table 4. Synthesis of the DCFA for the neighborhood markets in analysis.

Years	**1**	**2**	**3**	**18**	**19**	**20**
Total costs [€]						
Laurentino	4,050,467	19,251	20,405	30,419	31,028	31,649
Spinaceto	4,227,150	20,684	21,924	32,683	33,336	34,003
Tor de' Cenci	4,029,559	19,270	20,426	30,450	31,059	31,681
Vigna Murata	4,720,525	23,300	24,698	36,816	37,552	38,304
Total revenues [€]						
Laurentino	-	74,900	86,500	128,900	131,500	4,489,192
Spinaceto	-	104,900	121,100	180,500	184,100	4,732,863
Tor de' Cenci	-	79,900	92,200	137,500	140,300	4,475,711
Vigna Murata	-	126,300	145,700	217,300	221,600	5,301,543
Cash flows [€]						
Laurentino	*-4,050,467*	*55,650*	*66,095*	*98,481*	*100,472*	*4,457,543*
Spinaceto	*-4,227,150*	*84,217*	*99,176*	*147,817*	*150,764*	*4,698,860*
Tor de' Cenci	*-4,029,559*	*60,630*	*71,774*	*107,050*	*109,241*	*4,444,030*
Vigna Murata	*-4,720,525*	*103,000*	*121,002*	*180,484*	*184,048*	*5,263,240*

	Laurentino	**Spinaceto**	**Tor de' Cenci**	**Vigna Murata**
Discount rate	**3%**			
NPV [€]	**-380,000.00**	**120,000.00**	**- 280,000.00**	**310,000.00**

4.4 Hypothesis of a Project Financing Procedure for the Spinaceto Market

According to the requirement of the Public Administration, for the Spinaceto market a further insight of the analysis has been developed, by considering to borrow the logic of a public-private partnership mechanism (i.e. project financing) in the regeneration process [12]. The Public Administration intends to enhance the value of this market, which, due to the project's characteristics, is better suited than the other three for the realization of an attractive investment for a potential private operator.

In this scenario, the entrepreneur can lease the stalls at a market rent. Through an analysis on the commercial segment for the reference area of the Spinaceto market, a monthly unitary market rent equal to 20 €/m^2 per month has been assessed.

The feasibility analysis of the operation has been carried out using a DCFA over a potential concession period of thirty years. The cash flows of the operation have been actualized using a discount rate that reflects the specific investment risk, taking into account the assets, the location, the lease contract duration, inflationary prospects, and market expectations. By implementing the Weighted Average Cost of Capital (WACC) approach, assuming a financial structure composed of 40% equity and 60% debt, and respectively risk premium rates equal to approximately 13% and 6%, a discount rate equal to 8.87% has been assessed.

The development of the DCFA has allowed for the verification of the financial sustainability of the project financing initiative, with a NPV for the private entrepreneur equal to 410,000 €.

Figure 1 shows the development of the NPVs over the analysis period for the calculation of the Payback Period (PbP), that in this specific case is equal to approximately 23 years.

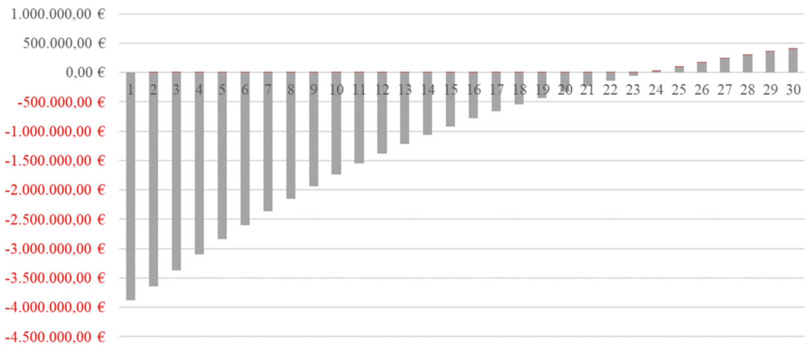

Fig. 1. Development of the NPVs of the project financing initiative for the Spinaceto neighborhood market.

5 Conclusions

This research has analysed the economic and financial aspects related to the regeneration projects of four municipal neighborhood markets in the periphery of the city of Rome. To this end, socio-economic investigations have been carried out to outline a reference framework for assessing the feasibility of the interventions. The development of the DCFA for each neighborhood market has allowed to verify the financial sustainability for the Vigna Murata and the Spinaceto markets, whereas for the Laurentino and the Tor de' Cenci markets the viability can be achieved by considering the "economic" effects, i.e. the spillovers related to the social and environmental benefits generated by the regeneration investments for the local contexts and the communities in the medium-long term.

The hypothesis of borrowing a public-private partnership [13] procedure for the revitalization of the Spinaceto market has demonstrated that the initiative is highly attractive for a potential private investor, as the NPV is equal to 410,000 € in a thirty years concession period, with a PbP equal to approximately 23 years.

With reference to the situation of a public management of the redeveloped assets, the synergistic value of the four interventions should be pointed out, able to ensure the balance sheet of the entire investment by taking into account the network of impacts that can be triggered off on the macro-area in analysis.

In recent years, there has been a trend towards the decentralization of neighborhood markets from historic centres to peripheral areas. This contingency is due to a number of factors, including the decline of the traditional retails in the city centres, the growth of suburban populations, and the need to provide for services to marginalized communities. The decentralization of neighborhood markets - as the regeneration of the existent ones - could have relevant benefits for peripheral areas [14]. These markets can help to revitalize these territories of the cities, provide economic opportunities and promote social inclusion.

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Eco-Social Work: Theoretical Foundations and Implications for Sustainable Inclusion

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Abstract. This paper explores the integration of Circular Economy principles with social work, focusing on the emerging field of Eco-Social Work. It examines the theoretical foundations and practical applications of Eco-Social Work, emphasizing its potential to address environmental and social challenges in an integrated and sustainable manner. Drawing on case studies and real-world examples, the paper illustrates how Eco-Social Work can be applied within social work organizations to promote sustainable practices and empower marginalized communities. The significance of this study lies in its exploration of a transformative approach to social work that bridges environmental sustainability and social equity. Specifically, the case study of Cascina Contina, a social enterprise based in Italy, highlighted in Sect. 3, showcases the practical implementation of Eco-Social Work principles, offering valuable insights into its impact on fostering inclusive development and addressing complex societal issues.

Keywords: Eco-Social Work · Circular Economy · Social Work Practices

1 Introduction

In recent years, the intersection between social work and environmental sustainability has gained prominence. This paper investigates the fusion of Circular Economy principles with social work, focusing on the emerging field of Eco-Social Work. The research framework encompasses both the theoretical foundations and practical applications of Eco-Social Work, emphasizing its ability to address environmental and social challenges in a cohesive and sustainable manner. Eco-Social Work challenges the conventional focus of social work solely on humans, acknowledging the interconnectedness between humans and the natural environment. This recognition underscores the importance of environmental issues as social justice concerns, with their resolution being essential for the well-being of individuals, communities, and the planet as a whole.

The origins of social work's attention to environmental issues can be traced back to the 1960s and 1970s, when Western nations grappled with energy and environmental crises, multiculturalism and civil rights. During this period, social workers began acknowledging the impact of environmental challenges on individuals and communities, particularly marginalized populations disproportionately affected by environmental

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degradation and resource depletion (Besthorn 2012). Despite this recognition, the integration of environmental sustainability principles within social work remains limited, with insufficient research in the field (Philip and Reisch 2015). However, there has been a recent resurgence of interest in exploring the potential of Eco-Social Work to address environmental and social challenges comprehensively and sustainably (Miller et al. 2012).

At the heart of this investigation lies a fundamental question: how does Eco-Social Work contribute to sustainable development and social equity through the incorporation of Circular Economy principles? To address this question comprehensively, the paper is structured as follows:

– In Sect. 2, we delve into the theoretical underpinnings of Eco-Social Work, examining essential concepts and frameworks that shape its approach. By scrutinizing these theoretical foundations, we aim to provide a nuanced understanding of Eco-Social Work's guiding principles.
– Sect. 3 ventures into the realm of practical applications and case studies, offering concrete illustrations of how Eco-Social Work can be effectively implemented within social work organizations. Through detailed analysis and real-world examples, this section sheds light on the operationalization of Eco-Social Work principles and their impact on societal well-being.
– Finally, Sect. 4 serves as a culmination of our exploration, presenting a conclusion that synthesizes key insights derived from our inquiry. In this concluding section, we reflect on the transformative potential of Eco-Social Work in reshaping economic structures and nurturing holistic well-being, paving the way for a more sustainable and equitable future.

2 Theoretical Foundations of Eco-Social Work

2.1 Significance of Eco-Social Work in Addressing Ecological and Social Challenges

Eco-Social Work provides a theoretical framework and practical strategies for addressing ecological and social challenges in an integrated and sustainable manner (Wang and Altanbulag 2022). It recognizes that the global ecological crisis, including climate change, biodiversity loss, and resource depletion, is intricately linked to social and economic inequalities. Eco-Social Work offers a multifaceted approach to address these complex issues by integrating environmental justice, sustainable development, and social work principles. By incorporating ecological perspectives into social work practices, Eco-Social Work aims to promote environmental stewardship, advocate for the rights of marginalized communities impacted by environmental degradation, and foster sustainable and equitable societies.

At the core of Eco-Social Work is the recognition of the interconnectedness between environmental and social systems, emphasizing the need to address environmental challenges through the lens of social justice. This approach acknowledges that vulnerable and marginalized populations bear the brunt of environmental burdens and are often excluded from decision-making processes that affect their well-being. By prioritizing the voices and experiences of these communities, Eco-Social Work seeks to create inclusive and participatory solutions that address both social and environmental concerns (Coates and Gray 2012). Furthermore, Eco-Social Work emphasizes the importance of collaborative and interdisciplinary efforts to address the ecological and social challenges. It encourages partnerships between social workers, environmental scientists, policymakers, and the community to advocate the development of innovative and sustainable solutions that consider the complex interplay between environmental factors and social dynamics (Schmitz et al. 2012).

In the following sections, we explore the theoretical underpinnings of Eco-Social Work in greater detail by examining key concepts and frameworks that inform its approach to sustainable inclusion and environmental justice. Additionally, we delve into the practical implications of Eco-Social Work in real-world contexts, highlighting its potential to affect positive changes at the individual, community, and systemic levels.

2.2 Theoretical Exploration of Eco-Social Work and Its Potential for Sustainable Inclusion

Eco-Social Work is founded on principles of sustainability, social justice, and ecological interconnectedness, challenging the traditional scope of social work by integrating ecological perspectives and acknowledging the inseparable relationship between environmental and social systems (Närhi and Matthies 2016).

2.2.1 Ecological Systems Theory

The ecological systems theory serves as a cornerstone of Eco-Social Work, highlighting the intricate interactions among individuals, communities, and their environment. This framework recognizes individuals as integral parts of broader interconnected systems influenced by environmental factors. Eco-Social Work adopts this perspective to comprehend the impact of environmental challenges on human well-being and advocate for inclusive and sustainable solutions within the larger ecological context (Coates and Gray 2012; Peeters 2011).

2.2.2 Environmental Justice Framework

Another foundational pillar of Eco-Social Work is the environmental justice framework, which underscores the disproportionate burden of environmental degradation and pollution on marginalized communities. This framework guides Eco-Social Work practitioners in addressing systemic inequalities leading to environmental injustices, advocating for the rights of vulnerable populations, and promoting inclusive decision-making processes that prioritize the voices of those most affected by environmental hazards (Schmitz et al. 2012).

2.2.3 Intersectionality and Social Work

Drawing from the concept of intersectionality in social work theory, Eco-Social Work recognizes the overlapping forms of oppression and privilege experienced by individuals and communities. Through an intersectional approach, Eco-Social Work aims to address the unique and intersecting environmental and social challenges faced by diverse populations, thus contributing to a more inclusive and equitable approach to sustainable development (Norton 2011).

2.3 Circular Economy as a Regenerative System

Eco-Social Work draws inspiration from the principles of the Circular Economy, recognizing that traditional linear economic models contribute to environmental degradation and social inequities. Therefore, Eco-Social Work aims to promote the transition towards a regenerative economic system that minimizes waste, promotes resource efficiency, and fosters sustainable development. By integrating the principles of the Circular Economy into social work practice, Eco-Social Work seeks to create a society that operates within the limits of natural resources, reduces its ecological footprint, and promotes social and economic well-being for all (Wang and Altanbulag 2022).

The discourse on the Circular Economy began with the work of scholars such as Walter Stahel and Ellen MacArthur (Ellen MacArthur Foundation 2013) advocating for a departure from the traditional linear production and consumption model to one that is restorative and regenerative. This circular approach aims to decouple economic growth from resource consumption and waste generation by prioritizing reduction, reuse, and recycling. It underscores the importance of designing products and systems for reusability, repairability or recyclability to minimize the utilization of finite resources and mitigate environmental impact. Additionally, the Circular Economy paradigm promotes the concept of “closing the loop,” where waste is perceived as a valuable resource and reintegrated into the production cycle. This discourse has gained momentum across various sectors as a sustainable strategy to address environmental concerns and advance social equity. This transition from a linear to a circular model aligns with the fundamental tenets of Eco-Social Work, emphasizing the necessity for holistic solutions that consider both environmental sustainability and social well-being. By expanding the discourse on the Circular Economy within the realm of Eco-Social Work, it becomes imperative to underscore the potential impact of regenerative systems on marginalized communities and vulnerable populations (Velenturf and Purnell 2021). The Circular Economy framework presents an opportunity to tackle environmental injustices by reimagining production processes, consumption patterns, and resource distribution in a manner that prioritizes inclusivity and equitable access. Through the promotion of regenerative practices, Eco-Social Work can contribute to the establishment of economic systems that not only mitigate environmental harm but also foster social resilience and empowerment, particularly among communities disproportionately affected by environmental degradation and resource depletion. For instance, consider the European case of “GreenWorks”, a community-based initiative in a rural area aiming to reduce waste and promote sustainable practices (https://greenworks.ba/green-works-project/). Through partnerships with local businesses and government agencies, GreenWorks collects and repurposes discarded materials, such as wood and metal, to create new products. This initiative not only reduces waste but also generates employment opportunities and fosters community resilience. By implementing Circular Economy principles, GreenWorks demonstrates how Eco-Social Work can address environmental challenges while promoting economic and social well-being at the local level.

Moreover, the discourse surrounding the Circular Economy invites critical reflections on the intersections among environmental sustainability, social equity, and economic systems. By broadening our conception of sustainability beyond environmental conservation to encompass economic and social dimensions, Eco-Social Work can actively engage in shaping policies, practices, and interventions that advocate for a more inclusive and regenerative approach to societal well-being (Prieto-Sandoval et al. 2018). This systemic approach underscores the necessity for collaborative and interdisciplinary efforts to comprehensively address complex challenges and promote sustainable inclusion. Through the integration of Circular Economy principles with social work, Eco-Social Work contributes to the transformation of unsustainable economic structures and the advancement of a more equitable society (Matthies et al. 2020).

2.4 The Holistic Perspective of Social Work

In social work, adopting a holistic perspective is paramount for comprehending the intricate interconnectedness among individuals, families, communities, and their environment. This perspective acknowledges that individual well-being is intricately influenced by a myriad of environmental, social, cultural, and economic factors. These factors encompass access to resources, educational and employment opportunities, social support networks, and the overall quality of the physical environment. Embracing this holistic approach empowers social workers to navigate complex dynamics, addressing immediate issues while targeting the underlying systemic problems (Närhi and Matthies 2016). Moreover, the holistic perspective in social work extends beyond merely identifying individual problems to encompass addressing broader social and environmental contexts that contribute to these issues. This approach facilitates a comprehensive understanding of challenges, laying the groundwork for effective systemic interventions. Guided by this perspective, Eco-Social Work plays a pivotal role in confronting systemic injustices entrenched within prevailing economic and social structures. Practitioners adeptly navigate intricate dynamics, recognizing and addressing the disproportionate impact of environmental degradation on marginalized populations (Belchior Rocha 2018).

The intersectionality of environmental justice and social inequality becomes palpable through the lived experiences of marginalized communities grappling with environmental hazards and resource scarcities. Aligned with Circular Economy principles, Eco-Social Work endeavors to rectify environmental injustices through advocacy for inclusive and regenerative practices. Central to Eco-Social Work is the notion of empowerment for individuals and communities facing systemic marginalization. By advocating for regenerative economic systems and equitable resource distribution, Eco-Social Work aims to rebalance power dynamics and foster agency at both individual and collective levels.

The case of the Portuguese eco-neighborhoods serves as an exemplary demonstration of the holistic perspective of social work in promoting environmental sustainability (Belchior Rocha 2018). Social workers actively engage with residents to address environmental threats, empower individuals within socially vulnerable communities, and foster community resilience. By understanding the intersectionality of environmental challenges and tailoring solutions to meet the diverse needs of community members, social workers integrate intersectionality into their practices, ensuring a comprehensive approach to addressing environmental issues. Through collaboration with diverse stakeholders and the utilization of technology and innovation, social workers contribute to the development of sustainable communities capable of adapting to environmental changes. This case study highlights the transformative role of social workers in advancing environmental justice and cultivating inclusive and environmentally conscious approaches to community development. By documenting and analyzing such success stories, social workers can draw inspiration and valuable insights to further their impact on promoting environmental justice and sustainable communities. With this practical example, the transformative potential of integrating Circular Economy principles into Eco-Social Work becomes evident. These illustrations demonstrate effective integration, addressing environmental injustices, fostering resilience, and contributing to sustainable and inclusive development. Such integration propels the advancement of equitable societies by reshaping unsustainable economic structures. By embracing regenerative systems and advocating for inclusive resource distribution, Eco-Social Work empowers social workers to prioritize holistic well-being and address systemic injustices. Through its commitment to empowerment and regenerative economic systems, Eco-Social Work emerges as a transformative force reshaping economic structures for sustainable and inclusive development, as evidenced in practical examples and case studies (Boetto 2016; Obeng 2023).

2.5 Circular Economy Principles Aligned with Social Equity and Well-Being

Circular Economy principles, rooted in notions of fair resource distribution, community engagement, and addressing systemic injustices, are inherently aligned with social equity and well-being. Through Circular Economy principles, Eco-Social Work aims to tackle environmental and social challenges at their roots, recognizing the necessity of systemic solutions that extend beyond individual behaviors or technological advancements (Liu and Flynn 2023). At its core, Circular Economy seeks to foster a regenerative economic system, minimize waste, and prioritize community well-being (Nikolaou et al. 2021). This foundational principle resonates with the ethos of social work, emphasizing the importance of inclusive and regenerative practices in addressing systemic injustices embedded in current economic and social structures (Jef Peeters 2012; Uehara et al. 2013).

The study conducted by Hoff offers a compelling example of how the integration of ecological science into social work education and practice aligns with the principles of the Circular Economy, well-being, and social equity (Hoff 1998). Hoff's research underscores the interconnectedness between ecological science and social sustainability, highlighting the importance of incorporating a multidisciplinary approach into social work education. By recognizing the intricate links between human health, cultural diversity, and ecosystems, social workers equipped with knowledge from ecological science can develop more comprehensive strategies for promoting social sustainability within communities. This holistic approach enables social workers to address the ecological dimensions of sustainability effectively, contributing to the well-being of individuals and communities. Furthermore, the study emphasizes the collaborative nature of addressing environmental challenges and promoting sustainable practices. By fostering partnerships with ecologists and other experts, social workers can leverage diverse perspectives to develop innovative solutions that prioritize equity, justice, and well-being for all individuals.

2.6 Exploration of the Most Recent Existing Theories and Frameworks Connecting Circular Economy and Social Work

Various theories link Circular Economy principles to social work, showcasing collaboration potential. Gibson-Graham's diverse economic approach broadens economic criteria, emphasizing social power's translation into economic power within community economies (Gibson-Graham 2008). Nelson and Timmerman propose an integrated model of sustainable community development, advocating for a holistic approach to address social inequality and environmental degradation (Nelson and Timmermans 2011). Altanbulag underscores the role of Eco-Social Work in bridging ecological development plans and traditional livelihood needs (Wang and Altanbulag 2022).

Scholarly works meticulously examine Circular Economy principles in social work, employing a case-study-centric methodology to highlight practical instances of Eco-Social Work initiatives. Researchers delve into the realization and impact of Circular Economy principles, offering insights into their integration into social work practices through in-depth case studies. Peeters (2011) delves into the practical dimensions of Eco-Social Work that incorporate Circular Economy principles, offering a benchmark for understanding the implementation and impact of such initiatives. This study is crucial because it provides insights into how Circular Economy principles can be effectively integrated into social work practices to address environmental and social challenges. By examining real-world examples and case studies, Peeters offers practical guidance for social workers and policymakers on how to adopt Circular Economy principles in their work, thereby advancing sustainable development goals. Additionally, Peeters' research serves as a benchmark for evaluating the effectiveness and scalability of Eco-Social Work initiatives, helping to identify best practices and areas for improvement in the field. Overall, this study contributes to a deeper understanding of the intersection between Circular Economy principles and social work, highlighting the importance of practical implementation strategies in achieving meaningful outcomes for communities and the environment. Matthies et al. (2020) conduct a meticulous examination of Eco-Social Work initiatives, offering nuanced insights into the practical application of Circular Economy principles within the realm of social work. This study is significant because it provides a comprehensive understanding of how Circular Economy principles can be effectively integrated into social work practices to promote sustainability and social equity. By analyzing a range of Eco-Social Work initiatives, Matthies and colleagues offer valuable insights into the challenges, opportunities, and best practices associated with implementing Circular Economy principles in various contexts. Their research not only sheds light on the potential benefits of adopting Circular Economy approaches but also identifies key considerations for practitioners and policymakers seeking to leverage these principles for positive social and environmental outcomes. These contributions underscore multifaceted dimensions of Circular Economy principles merged with social work practices, enriching the theoretical fabric. They provide concrete examples and case studies, contributing to knowledge about integrating Circular Economy principles into social work. The potential for collaborative efforts is reinforced, emphasizing their role in realizing sustainability goals and fostering inclusive development.

Boetto et al.'s (2022) study delves into the dynamics of Circular Economy principles within the realm of social work, with a particular focus on sustainable community development. This research is significant because it provides valuable insights into how Circular Economy principles can be effectively applied to address community development challenges while promoting sustainability and social equity. By examining the intricate interactions between Circular Economy principles and social work practices, Boetto and colleagues offer nuanced perspectives on navigating the complexities of community engagement. Their study not only highlights the potential benefits of incorporating Circular Economy approaches into social work interventions but also identifies practical strategies for overcoming barriers and maximizing positive impacts. Obeng's (2023) research is dedicated to exploring the operationalization of Circular Economy principles within the field of social work. This study is particularly valuable as it contributes to enriching theoretical discourse surrounding Eco-Social Work and offers practical insights into the implementation of Circular Economy principles in real-world settings. By focusing on the practical application of Circular Economy concepts within social work practice, Obeng sheds light on how these principles can be effectively translated into actionable strategies and interventions.

3 Practical Applications and Case Studies

3.1 Real-World Examples of How Eco-Social Work Can Be Applied in Social Work Organizations: CNCA's Contribution

Embarking on an exploration of the practical manifestations of Eco-Social Work within the realm of social work organizations, the Coordinamento Nazionale Comunità di Accoglienza (CNCA) emerges as a paradigmatic exemplar. This umbrella organization encompasses a vast network of approximately 240 entities spread across Italy. This network comprises a diverse array of institutions, ranging from social cooperatives to voluntary associations and religious entities. United under the banner of the CNCA, these organizations collectively form a formidable force at the forefront of tackling prevalent societal challenges and combating marginalization.

The CNCA's expansive reach and multifaceted composition underscore its pivotal role in spearheading initiatives that resonate deeply with social impact. Within its extensive network, the CNCA fosters collaboration and synergy among a diverse array of stakeholders, facilitating a concerted effort to address pressing social issues. This collaborative ethos not only amplifies the impact of individual organizations but also fosters a sense of collective responsibility towards societal well-being. Furthermore, the CNCA serves as an example of innovation and best practices, offering practical implementations that exemplify the principles of Eco-Social Work in action. Through a combination of advocacy, community engagement, and grassroots initiatives, CNCA-affiliated organizations are actively involved in effecting tangible change at both the local and national levels. Whether through sustainable development projects, social inclusion initiatives, or advocacy campaigns, the CNCA's endeavors resonate with a profound commitment to fostering holistic well-being and societal transformation.

3.2 Cascina Contina (Rosate, Milano, Italy)

Situated amidst the landscapes of the Milan hinterland and operating under the auspices of the Coordinamento Nazionale Comunità di Accoglienza (CNCA), Cascina Contina stands as a beacon of innovation and resilience within the realm of Eco-Social Work. This distinctive social enterprise embodies a holistic approach to rehabilitation, intertwining therapeutic interventions with nature and agriculture to foster healing and empowerment among individuals undergoing addiction treatment. At the heart of Cascina Contina's ethos lies a profound recognition of the therapeutic potential inherent in nature's embrace. Drawing inspiration from the restorative power of the natural world, this initiative pioneers a novel approach to addiction recovery, one that transcends conventional treatment modalities. Through immersive experiences in agriculture and nature-based activities, individuals grappling with addiction are provided with a transformative pathway towards recovery and renewal. Whether tending to the soil, cultivating crops, or engaging in hands-on agricultural practices, participants are afforded opportunities for self-reflection, growth, and reconnection with both themselves and their surroundings.

Moreover, beyond its immediate therapeutic benefits, Cascina Contina's engagement in agricultural endeavours carries profound implications for sustainability and environmental stewardship. By actively involving individuals in meaningful agricultural activities, the initiative not only fosters personal growth and empowerment but also contributes to the broader goal of promoting sustainable practices within the community. Through hands-on participation in ecological farming practices, such as organic cultivation techniques and permaculture principles, participants gain firsthand experience in sustainable living and environmental conservation. In doing so, Cascina Contina exemplifies the synergy between individual well-being and ecological sustainability, demonstrating how Eco-Social Work can serve as a catalyst for positive change at both the personal and societal levels.

Furthermore, the practice of consuming what is grown on-site promotes nutritional awareness and healthy eating habits and instills a deeper appreciation for the labor and resources involved in food production. Participants develop a heightened sense of mindfulness and gratitude as they partake in meals crafted from the fruits of their labor, forging a deeper connection to the land and fostering a culture of sustainability and environmental stewardship. Thus, Cascina Contina's farm-to-table approach transcends mere sustenance, serving as a potent catalyst for personal growth, community resilience, and ecological consciousness among all who partake in its offerings.

In addition to its therapeutic programs, Cascina Contina operates a welcoming restaurant, serving as a communal gathering space where individuals, groups, and the broader community converge to share meals, stories, and experiences. This communal dining experience fosters a sense of belonging and camaraderie, nurturing social connections and mutual support among participants and visitors alike.

3.3 Cooperativa Insieme (Vicenza, Italy)

Cooperativa Insieme, nestled in Vicenza, Italy, emerges as a chance of hope and empowerment for individuals navigating the complexities of social marginalization. Rooted in sustainability principles and Circular Economy practices, this cooperative exemplifies a holistic approach to community development that transcends conventional boundaries. At the core of Cooperativa Insieme's mission is a commitment to fostering inclusive opportunities for individuals from disadvantaged backgrounds, including those who have grappled with incarceration or addiction. Through a diverse array of initiatives, the enterprise empowers these individuals to reclaim agency over their lives and contribute meaningfully to society. One such initiative revolves around recycling and reuse activities, wherein participants are actively involved in salvaging materials, repurposing goods and minimizing waste. This hands-on engagement for sure promotes environmental stewardship and cultivates valuable skills and competencies, paving the way for sustainable livelihoods and economic independence.

Moreover, Cooperativa Insieme operates a network of second-hand shops, serving as vibrant hubs of community engagement and social interaction. Here, individuals have the opportunity to browse and purchase pre-loved items, contributing to the Circular Economy while also supporting the cooperative's endeavors. Importantly, these shops serve as more than just retail spaces; they are lively gathering spots where patrons can engage in discussions about sustainability, reflect on their consumption habits, or simply enjoy a friendly chat over coffee at the on-site bar.

By championing initiatives that bridge the gap between environmental sustainability and social inclusion, Cooperativa Insieme epitomizes the essence of Eco-Social Work. Beyond mere rhetoric, the enterprise's endeavours embody a tangible commitment to fostering holistic well-being and resilience among marginalized communities. Through meaningful employment opportunities, skill development initiatives, and community spaces, individuals on the fringes of society are empowered to transcend barriers, rewrite their narratives and chart a course towards a brighter future.

4 Conclusion

In conclusion, the practical examples presented, such as the initiatives led by the Coordinamento Nazionale Comunità di Accoglienza (CNCA), showcase the tangible impact of Eco-Social Work in fostering regenerative economic systems and promoting sustainability within social work organizations. By highlighting the successes of initiatives like these projects, which incrementally advanced the adoption of Circular Economy principles, we underscore the transformative potential of integrating these principles into social work practice. By integrating the principles of circularity, sustainability, and social inclusivity, organizations such as Cascina Contina and Cooperativa Insieme serve as trailblazers for holistic and regenerative approaches. Thus, they address societal challenges while simultaneously fostering the well-being, resilience and empowerment of individuals navigating adversity. These practical applications serve as beacons, guiding the way towards a future where Eco-Social Work becomes an integral aspect of social work organizations, contributing to a more inclusive and sustainable societal paradigm.

Moving forward, further studies could explore the long-term effects and scalability of such initiatives, delving into the evolution and sustainability of regenerative economic models within social work organizations. Additionally, research could focus on refining strategies for community engagement and participation, as demonstrated by the CNCA network, to enhance inclusivity and effectiveness in implementing Circular Economy principles. By directing attention towards real-world examples and potential avenues for future research, we pave the way for a more comprehensive understanding of how Eco-Social Work can contribute to sustainable development and social equity. This approach emphasizes the importance of practical applications and empirical studies in guiding the evolution of Eco-Social Work practice and theory, ultimately contributing to a more sustainable and inclusive future.

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AI Algorithms in Real Estate: A Roadmap to Precision Housing Price Predictions

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Abstract. This article examines the application of artificial intelligence (AI) in real estate, with a particular focus on its role in housing price forecasting. The study starts with the hedonic pricing model and conducts a comprehensive review of existing models. These models are divided into several groups, including traditional statistical methods such as regression and decision trees, as well as advanced machine learning methods such as random forests, support vector machines, K-nearest neighbors, gradient boosting machines, neural systems, networks and recurrent neural networks, convolutional neural networks, finite periodic units, generative adversarial networks, transformer model, XGBoost, fuzzy models, operation research and analytic hierarchy process.

The analysis evaluates these models based on various criteria, including ability to learn online, sensitivity, handling of missing values, robustness, scalability, prediction speed, and linearity. Understanding the strengths and limitations of each model for predicting housing prices can provide real estate practitioners and researchers with valuable insight into selecting appropriate AI models for specific applications.

Keywords: Real Estate · Valuation · Artificial Intelligence · Forecasting · Hedonic Prices

1 Introduction

In the evolving world, artificial intelligence (AI) has become a transformative element that is redefining every aspect of our society. In real estate, the need for accurate appraisals is not limited to buying and selling transactions, but also includes tax matters, surveys and building environmental management. In this case, the hedonic price plays a crucial role in the evaluation of the product by evaluating its inherent properties. Such an approach helps not only to make decisions in the real estate market, but also to understand and manage the built environment.

Based on detailed analysis, predictive models can be created that become the basis for automation, including the development of Automated Valuation Systems (AVMs). This process not only simplifies valuation, but also incorporates machine learning (ML) elements to continuously adapt to changing market dynamics.

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The different methods dedicated to property valuation using AI have grown in recent years [1, 2], in which the primacy of manual methods has passed to complex methods based on computational calculation. This transformation addresses the growing need for precision in a dynamic real estate environment. AI models are grouped by features and include linear techniques such as linear regression that are ideal for simple models. In classification, logistic regression, and support vector machines (SVM) stand out for their capabilities in binary decisions and multidimensional spaces. Tree-based methods such as decision trees (DT) and random forests (RF) [3] can handle complex relationships. Gradient boosting techniques (GBM) [4] improve accuracy through sequential construction, marking a significant advance. Neural networks (NN) and convolutional neural networks (CNNs) [5] are good at modeling complex relationships and visual data, respectively. Transformer models (TM) are effective for sequential data. Finally, fuzzy models (FM) [6] use fuzzy logic and provide valuable perspectives in uncertain environments. These advanced models not only improve the accuracy of property valuations, but also adapt to the ever-changing complexities of the real estate market and redefine property valuations in the digital age.

Articles showing the advantages of random forests over other models [2, 7] [8], however, other authors highlight the accuracy of gradient boosting [8], artificial neural networks [9], nonlinear regression models supporting vector machines as well as the advantages of Fuzzy logic when it comes to including the particularity of real estate assets [9]. Also [7] highlights the importance of including visual information in the process and [10] raises the contribution of geographic information. There is a lack of full consensus between the different methods used to optimize house price estimation, and different tools are used to achieve different results, errors, and information. In addition to the above models, there is a growing application of quantum computing in the property sector [11–13], again with the aim of optimizing investment opportunities with a significant increase in computing power compared to the above tools.

2 Methodology

The main objective of this research is to highlight different AI tools that can be used for property valuation. By examining how each tool addresses the complexities of property valuation, we aim to gain a comprehensive understanding of the wide range of opportunities these methods bring to the real estate industry. This approach, based on a review of scientific research, allows us not only to recognize the diversity of AI methods available, but also to understand the evolution of these tools and their impact on the overall effectiveness of real estate appraisals. A selection of fourteen scientific articles has been made that include the comparison of two or more valuation methods in different regions of the world. In them you can see the differences obtained in the results depending on each method, considering preferable methods depending on the error obtained.

3 Results

Table 1 documents the relationship between the patterns of the examined articles and highlights the centrality of the regression models when comparing results. Differences in the amount of data used are highlighted, showing significant differences in data collection and analysis methods between models. These changes in sample size may affect the generalizability and robustness of the results. The table again shows the differences in the amount of data that must be considered when interpreting and comparing the results of the different models evaluated.

Table 1. Articles that relate to the different models under study.

Document	Year	Country	Samples	ML Method
[8]	2022	Australia	77,063	Regression, SVM, RF
[14]	2012	Russia	2,848	Regression, RF, KNN, NN
[15]	2011	Lithuania	100	Regression, SVM
[7]	2023	United States	1,018	Regression
[16]	2024	Spain	+5 million	Regression, RF
[17]	2022	Taiwan	209,402	Regression, SVM, DT, NN
[9]	2019	Italy and Poland	37	Regression, NN, FM
[18]	2018	Spain	2,266	SVM, DT, KNN, NN
[19]	2022	Russia	4,294	RF, DT
[20]	2023	Hong Kong	24,317	RF, KNN,
[21]	2020	Hong Kong	39,554	RF, GBM
[22]	2023	Australia	42,335	NN, CNN

The graphical representation in Fig. 1 describes the complex relationships between the main articles examined, emphasizing their interrelationships to reduce estimation error. This visual image not only serves as a detailed map that reveals the fundamental relationships between the components of the analysis, but also highlights the importance and complexity of the task of achieving maximum accuracy of assessment. Each line and connection in the diagram represent the interdependence and interaction of the elements, providing a rich visual representation that helps understand the dynamics of the study.

Figure 1 visually depicts the interconnectedness of various (ML) methods. The line thickness represents the strength of the relationship between the models, with thicker lines indicating stronger ties. Light blue represents the ML method with the most citations, followed by dark blue, light green, dark green, red, and orange. Notably, fuzzy models stand apart, demonstrating minimal connections to other ML approaches.

The representation in Table 2 describes the complex relationships between the main articles examined, emphasizing their interrelationships in an effort to reduce estimation error. This visual table not only serves as a detailed map that reveals the fundamental relationships between the components of the analysis, but also highlights the importance and complexity of the task of achieving maximum accuracy of assessment. On the one hand, the difficulty of interpreting the results can be observed as the models become more complex. Obtaining more precise results does not have to allow the understanding of the relationships between the different elements that make up the price.

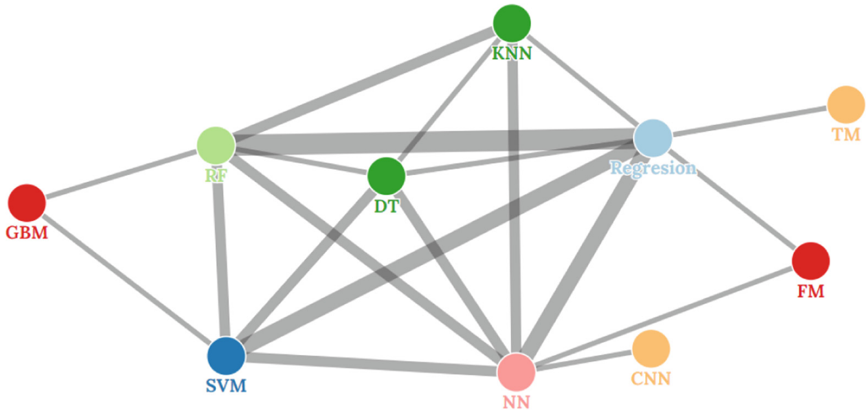

Fig. 1. Relations between methods of Table 1. Made with 'Flourish'

Table 2 provides a comprehensive framework for evaluating machine learning techniques for real estate valuation, highlighting their suitability for specific tasks and performance characteristics.

- Supervised Learning: Supervised learning models are well-suited for real estate valuation due to their ability to learn from labeled data and generate accurate predictions for house prices based on property attributes.
- Usability for Regression: Regression models, particularly those that excel in handling non-linearity, are particularly valuable for real estate valuation, as they can capture intricate relationships between various property features and accurately estimate house prices. While Transformers and CNNs are not traditionally employed for regression, this article explores their effectiveness in this domain.
- Interpretability: Interpretable models are essential for building trust and transparency in real estate valuation, as they enable stakeholders to understand the factors influencing the model's predictions and identify potential biases.
- Feature Scalability: Scalable models can effectively handle the vast amount of data and multiple interconnected variables typically involved in real estate valuation, ensuring efficient and accurate assessments.
- Robustness to Outliers: Robust models are crucial for real estate valuation, as they can withstand the presence of outliers and prevent them from significantly impacting the model's predictions.

4 Discussion

The current landscape of the real estate industry shows a dual nature of property valuation, where regression models play a vital role as comprehensive benchmarks versus the latest AI techniques. Regression as a reliable traditional method forms an easily understood and widely used basis that can serve as a benchmark for evaluating the effectiveness of more advanced methods. However, there is a clear trend to adopt more complex and powerful models that challenge the limitations of traditional approaches.

Table 2. Main characteristics of the studied models. ● general existence of relationship, ○ general absence of relationship.

Model	Supervised Learning	Usability for Regression	Interpretability	Handling Non-Linearity	Feature Scalability	Robustness to Outliers
Regression	●	●	●	○	●	●
Support Vector Machines	●	●	○	●	○	○
Random Forest	●	●	○	●	●	●
Decision Trees	●	●	●	●	○	●
K-Nearest Neighbors	●	●	○	●	○	○
Neural Networks	●	●	○	●	○	○
Fuzzy Models	●	●	●	●	●	●
Gradient Boosting Machines	●	●	●	●	●	●
Transformer Models	●	●	○	●	○	○
Convolutional Neural Networks	●	●	○	●	○	○

Notable contributions include support vector machines, random forests, and neural network models. Thanks to AI's ability to handle non-linear relationships and complex patterns, these advanced models overcome the limitations of traditional regression methods and provide greater accuracy in property valuation. The ability of these models to capture the complexities of today's real estate markets signals a shift toward more adaptable and efficient approaches. In addition, the revolution in the real estate industry is also manifested in the innovative use of AI technologies in the analysis of visual and geospatial information. The combination of these tools has transformed real estate valuation, allowing for a more detailed and specific understanding of the real estate environment. The ability to interpret visual patterns and geospatial data not only enriches real estate valuations, but also provides a more comprehensive and relevant view of the dynamic real estate landscape. Overall, the integration of advanced AI techniques with visual and geospatial data highlights a new paradigm for optimizing property valuation accuracy and relevance, marking an important turning point in the development of the real estate industry.

The articles address the difficulty of predicting house prices, highlighting the difficulty of obtaining a reliable estimate of prices due to the large number of variables both intrinsic and extrinsic to housing [17]. More traditional models are used, which achieve an accuracy of around 90% [4, 8], with the expectation that their estimates will improve significantly.

Models perform better at the sub-area level than at the area or city level [8], which is accompanied by a preference for spatial modelling [5]. Similarly, there is a growing use of images with artificial intelligence tools that allow quantitative data to be complemented with qualitative data [7], in complex forms of analysis that train decentralised algorithms that can be used both openly and privately.

In terms of concrete methods, there are several works based on different datasets that obtain higher quality predictions through RF models [8, 16, 19]. However, this capability is confronted with other models such as CNN [10] or fuzzy models [9]. Thus, a wide range of possibilities for price estimation can be observed, where the results show the suitability of combining different methods.

The introduction of precision housing price predictions through multidisciplinary approaches based on integrating quantum computing and genetic algorithms in a local real estate market segment has been scarcely used in earlier works, especially in those concerning studies focused on cities with high market tightness [11]. Since the issue of housing market concerns civil society, more and more researches have regarded it as a paramount problem for the greater good of all. Because of this, in recent years, quantum machine learning has taken advantage in finding constructive answers to these economic questions [12]. In addition, the organization of the most recent research works can help in paving the way for quantum machine learning (QML) researchers, integrating thus various study fields, such as machine learning (ML), to enhance classical algorithms in the field of Real State [13].

5 Conclusions

In summary, this study highlights the great interest in the literature for the ongoing search for more accurate models to estimate market prices in the real estate industry. Although traditional regression methods are still popular, there is a recurring phenomenon in which a large number of analysis results are compared to those obtained using regression, justifying the need to explore more advanced and efficient alternatives. Among these alternatives, random forests stand out, becoming a significant contributor to more accurate results. In addition, the last decade has seen significant changes with the inclusion of new tools such as image analysis and geospatial techniques that have contributed significantly to the accuracy of property valuation. This panorama demonstrates the vitality of continued research and shows a clear trend towards the integration of innovative methods that enrich the understanding and accuracy of property valuation.

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Sustainability in Corporate Governance and Banking

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Abstract. In short, regulatory and social impulses have directed the actions of the banking enterprise toward issues of social responsibility, in order to acquire, preserve and increase consensus around its strategic-operational choices under a constraint of responsiveness to instances and needs, not only economic, on the part of the various stakeholders with which it weaves relationships to ensure its survival in a highly competitive environment (Chih H. L., Chih H. H., Chen T. Y. (2010), "On the determinants of corporate social responsibility: international evidence on the financial industry", Journal of 130 Business Ethics, vol. 93, n. 1: 115–135; Barile S., Sancetta G., Simone C. (2013), Business Management, Cedam, Padova; Oliveira et al., .Meditari Accountancy Research 27:196–227, 2019). In particular, any negative impact of such factors, so-called "ESG risks," may manifest itself through the traditional risk categories (credit, market, liquidity, and operational) in a double-materiality perspective (financial and environmental), as institutions may be affected (outside-in perspective) through their counterparties or invested assets, which in turn may be affected by (outside-in perspective) or impacted by (inside-out perspective) ESG factors. Both perspectives should be taken into account when assessing ESG risks. This short paper is intended to make a contribution to the continuing evolution of risk related to ESG variables in banking operations as understood in risk assessment and management.

Keywords: ESG · Banking · Corporate

1 Introduction

Profound changes have affected in the recent past the scenario within which businesses are called upon to operate, and it is precisely in the changing environment that the evolution of business characteristics and governance logics finds essential explanatory sources. The change has been articulated along three lines, separable only for the sake of expository clarity, but which in reality continually interpenetrate: the pervasiveness of the sustainability perspective for business survival, the rapidity and pervasiveness of technological progress and business innovation processes, and the evolution of the regulatory environment.

The above phenomena are also affecting financial intermediaries with increasing significance, given the role they play in the economic and social development of the

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reference context in which they are inserted and their consubstantial attention to the governance of the risk inherent in the great changes and transformations affecting the economy and society.

In particular, the regulatory intent to introduce a model of sustainable financial intermediation aimed at promoting economic growth that is in line with sustainability implies a significant challenge for the governing body, given the complexity of such inclusion in companies' strategic and operational processes.

Complexity that stems from the cultural, governance and management changes that the recalled sustainable financial intermediation model requires, as well as the need to flank the identification of sustainability risks with methodologies of assessing the degree to which its credit portfolio is aligned with the new sustainability objectives, with concomitant transparency regarding risks arising from specific sectors.

In this context, this paper focuses on the pervasiveness of sustainability in the governance of banking firms, including in light of recent guidance from European supervisors, and contributes to the literature on the topic by way of both theoretical and empirical.

2 The Relationship Between Sustainability and Performance in the Bank

The pronounced discontinuity effect from the past induced by the growing focus on sustainability combined with the central role assumed by financial firms, especially banks (the subject of this paper), fosters the emergence of new (larger) dimensions and strategic spaces-opportunities and threats-with the consequent need to make new action-reaction choices.

Also considering the criticality of the reputational and fiduciary factor on which the financial intermediation (Ruozi 2016; Gangi et al. 2019), the ability of banking firms in responding to such instances can provide a valuable opportunity to seize new strategic-operational opportunities, also in light of the role as a propulsion for change that they play (Furrer et al. 2012; Buranatrakul and Swierczek 2017).

In particular, banking enterprises, also stimulated by the impulses coming from the.

supervisory authorities, have declined their strategies by considering a relationship three-dimensional relationship of risk, return and social impact (Freeman 1984; Coulson 2009; Amini and Bienstock 2014; Ziolo et al. 2019), also in the awareness that reputation can be an element of competitive advantage competitive advantage (Porter and Kramer 2006; Wu and Shen 2013; Dell'Atti et al. 2017; Forcadell and Aracil 2017) that can expand the customer base and make its business model less price sensitive (Gangi et al. 2019).

The goal becomes, therefore, to seek the best combination of the elements that make up this three-dimensionality over a medium-to long-term horizon term (Baldini et al. 2018) and, at the same time, promote consistency between trajectories of long reach and initiatives in the short frame.

In this context, the regulatory process aimed at ensuring standards of reliability, consistency and comparability, must materialize in the adoption of indicators of common sustainability, such as those proposed by EU Regulation 2019/2088, with the ultimate goal of removing possible frictions and barriers in the single capital market.

In short, regulatory and social impulses have directed the actions of the banking enterprise toward issues of social responsibility, in order to acquire, preserve and increase consensus around its strategic-operational choices under a constraint of responsiveness to instances and needs, not only economic, on the part of the various stakeholders with which it weaves relationships to ensure its survival in a highly competitive environment (Chih et al. 2010; Barile et al. 2013; Oliveira et al. 2019).

This mandate requires the adoption of a holistic approach that is reflected crosswise on different levels of the business model, through (i) the adoption of specific quantitative/qualitative elements in the Risk Appetite Framework (RAF) and in the strategic planning, (ii) the adoption of specific collection and deployment policies, and (iii) the declination in the different business units for products and services in line with the customers' needs.

In particular, any negative impact of such factors, so-called "ESG risks," may manifest itself through the traditional risk categories (credit, market, liquidity, and operational) in a double-materiality perspective (financial and environmental), as institutions may be affected (outside-in perspective) through their counterparties or invested assets, which in turn may be affected by (outside-in perspective) or impacted by (inside-out perspective) ESG factors. Both perspectives should be taken into account when assessing ESG risks.

In other words, the bank may be subject to such risks directly, i.e. directly on its business model, policies, governance, and risk management, or indirectly, that is, through counterparties (entrusted and no entrusted).

In the case of Italian banks, Angelico et al. (2022) point out that compared to past years, awareness and attention to risks pertaining to climate change has increased, but the dissemination of best practices for full integration into business strategies still remains insufficient. There is still a need for considerable efforts regarding the assessment of climate impacts on the financial system, which suffers from poor information availability and serious difficulty in appreciating the cross-cutting effects of environmental impacts on the real economy and the financial system.

As pointed out by Rutigliano (2020), the context does not help, as, on the one hand, the one hand, the transformation of the banking industry does not facilitate the conditions for restoring of favorable starting conditions, on the other hand, supervisors continue to prioritize capital and compliance with prudential requirements, while the link with the territory is no longer considered a sufficient reason to support a model of "traditional" intermediation. At the same time, banks, increasingly pressured by the constraint of competition and requirements, need to place greater centrality to their relationship with stakeholders and the satisfaction of the demands made by the latter, now no longer of a purely economic nature.

One fact emerges, compliance with prudential requirements is a necessary but not sufficient for the restoration of the core values on which business must be based of business to achieve sustainability, in a context where the contribution of the stakeholders (engagement) is fundamental to building new strategies (Rutigliano 2020).

In addition, the supervisory authority's guidelines on the issue at hand, that is, of valuing sustainability in the contexts depicted above, faces an objective limitation: the need for information. In conclusion on what has been argued so far, financial firms must continue to cultivate a progressive attunement with stakeholders, seeking a coexistence between the industrial dimension and the sustainable dimension (which pushes for differentiation even in values from competitors). Such coexistence can be complicated but it is fruitful, and needs, therefore, to be constantly nurtured with attention to contexts and innovative insights.

3 Conclusions

The demands for sustainability from the evolution of the economy and society have influenced with increasing pervasiveness the established relationships between economics and finance in corporate governance and the latter's relationship with its context, gaining relevance in terms of breadth and topicality. Amplitude, in that the theme of sustainability transcends the internal characteristics of the enterprise to invest the relationships between the regulatory, production and financial systems. Topicality, in that it is the subject of particular attention by scholars and practitioners who consider the relationship between economics, finance and sustainability crucial to the achievement of efficient and effective forms of organization of industrial production.

Sustainability, therefore, influences the greater or lesser availability of resources (understood in a broad sense, such as financial, economic, know-how, accreditation, image, opportunity or chance) that, consequently, support and fuel the process of technological innovation that is indispensable for the achievement of competitive advantage and, ultimately, survival.

While ESG rating judgments have the advantage of being easily intelligible, they are characterized by a considerable degree of methodological heterogeneity, which contributes to increasing the nebulosity of the phenomena valued, with representations potentially undermining the efficiency of financial markets. In this sense, the discordance of the methodological approaches used is to be primarily attributable to the combination of (i) a theoretical framework that is not universally agreed upon (unsupported ESG definition, opacity of the elements underlying individual ESG factors, lack of universally valid and recognized) and (ii) a heterogeneity of appreciation of observed phenomena (lack of a shared definition of materiality and different techniques for assessment, aggregation and weighting of the underlying data).

Finally, returning to a theoretical reading of the topic at hand, we point out that the sustainability within the enterprise, understood as a system of decisions, presents profiles of theoretical reflection that are still open, in particular about the role it assumes in business decision-making processes and its relations to the relevant objectives and criteria decision-making.

Sustainability, studied as much from the perspective of drivers and overarching goals and objectives as well as in that of the criteria underlying business decision-making, with the underlying possible relationships with traditional goals and criteria, appears increasingly to be emerging, in the recent evolution of the socio-economic scenario, as an intrinsic aspiration of entrepreneurial finalism.

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A GIS-Based AVM for the Land Market Value Appraisal According to the Market-Oriented Approach

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Abstract. Recently, the use of IT tools in the assessment of real estate properties has become very popular among appraisal specialists, bankers, and researchers in this field. Many automatic valuation models (AVMs) using different statistical and mathematical models, such as regression, neural networks, and fuzzy logic, and based on different technologies have been proposed and developed with the purpose of appraising the value of a property. In this paper, combining GIS tools and the basic principles on which the market-oriented approach is based, we suggest a GIS-*based* AVM that is useful for assessing land market value, believing that the complex nature of this type of property can be well described by the aforementioned GIS tools. We argue that the development of this model provides useful insights for public administrations to support them in the definition of management actions of the local real estate sector concerning, for example, practical purposes such as tax or expropriative compensation quantification.

Keywords: Land Market Value · Appraisal · Market Oriented · Geographic Information Systems · Automated Valuation Methods

1 Introduction

The process of land valuation involves evaluating the characteristics of a specific area. This procedure can be characterized as a meticulous assessment of the landed property value based on knowledge and expertise. Nonetheless, the primary objective of land valuation is to establish a value, which is typically preceded by terms such as market value or benefit value [1]. The land value is typically expressed as either a capital value or an annualized economic rent [2]. In practice, the appraisal of land is a judgement made by a professional, and it is based on a variety of data and the characteristics of the land, such as the market value of the land and nearby buildings, estimates of reconstruction

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costs, and existing zoning permits [3]. According to Fattinanzi et al. [4–6], the land market value can be obtained by applying two different methods: (i) a *direct method*, if information (known prices and characteristics of comparable properties) regarding similar properties is available (the same type of area, similar floor area ratio and purpose, and a similar legislative or administrative context); and (ii) an *indirect method*, namely the transformation value method, which appraises a real asset's transformation value, which corresponds to the current market value of the asset in relation to the tangible and legally admissible possibilities of its transformation [7].

It is a common understanding in land valuation that the value and potential of a property are fundamentally determined by its location. If we consider two identical buildings, one situated in a peripheral area and the other in a central area, it can be assumed that the construction cost and the depreciation rate remain constant. However, it is noteworthy that the central property has a higher market value than the property located in the suburbs, owing to the position income associated with the land [8–10]. The well-known statement *"location, location, location"*, used by real estate agents to describe the three main factors to consider when picking a home, summarizes the concept thus far exposed, highlighting that location is one of the most significant influences on a property's worth. All of these findings underscore the significance of spatial factors in the decision-making process of land valuation.

Several physical and economic characteristics must be carefully considered in a land valuation procedure to determine the land market value. Certain of these characteristics are inherent to the land, while others are derived from external or environmental factors. Due to the complexity of the land valuation process, which necessitates the identification and assessment of all the factors that impact its valuation, providing property owners with an easy-to-understand explanation of their property's valuation remains a persistent challenge for planners and assessors [11, 12]. Currently, GIS tools that can perform all of these complex tasks are available. GIS provides a technical platform on which market analysis and spatial representation of property information can be shown in the form of maps [13]. The capabilities of GIS facilitate the administration of geographical data and enable the optimal utilization of location data, which is essential for the accurate land assessment.

In recent years, the automated valuation model (AVM) has been widely adopted in the real estate appraisal sector [14]: an AVM is a software system, often based on online data and resources, that can produce a property evaluation in a semiautomatic way [15, 16].

Given the above, combining GIS tools and the basic principles on which the market-oriented approach is based, in this paper we briefly present a GIS-*based* AVM that is useful for assessing land market value, exploiting the potential of analysis offered by GIS systems. Although the research is at an earlier stage, we argue that the development of the proposed model can provide useful insights for public administrations, especially for practical purposes such as tax or expropriative compensation quantification.

2 Materials and Methods

The materials and methods employed in this research is described in this section. Specifically:

The first subsection aims to present the fundamental coefficients involved in most market-oriented appraisal procedures, namely the similarity, reliability and composite coefficients;
The second subsection aims to present the market segment comparison methodology;
The third subsubsection presents a brief description of the proposed land valuation AVM; the knowledge of the aforementioned materials is functional for understanding the methodology itself.

2.1 The Rationality Measures: Similarity, Reliability and Composite Coefficients

Market-oriented appraisal procedures assume that the appraised property's value is closely related to the selling prices of similar properties within the same market area [17]. Similar properties are called *comparables*. Applying these procedures, the appraisers must identify several similar properties among all those that have recently been sold [18]. It is obvious that it is not possible to select properties identical to the subject, but it is important that the selected comparables are as similar as possible to the subject. According to this consideration, the process of finding comparables must consider "the similarity degree", which establishes a measure of comparability between the subject and the comparable under consideration. A second consideration of the comparable method, as well as any other procedure, is that the output data, namely the appraised value, are heavily dependent on the accuracy and reliability of the input data, namely, the sale transaction data [19]. These factors may also be affected by contingent circumstances and thus may present different degrees of "reliability" for appraisal purposes. In summary, the process of finding the best comparables must consider, at the same time, the similarity and the reliability degree of the sale data, which are fundamental conditions for applying a comparable method.

The coefficients presented below, which are able to measure the similarity and reliability degree of a comparable property, have been theorized by Salvo and De Ruggiero [19].

The similarity coefficient SC^j of a generic comparable j can be defined as follows:

in terms of absolute value

$$SC_a^j = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}\left|\frac{x_{ij}-x_{i0}}{\overline{x_i}}\right| - \sum_{i=1}^{n}\left|\frac{x_{ij}-x_{i0}}{\overline{x_i}}\right|}{(m-1)\cdot\sum_{j=1}^{m}\sum_{i=1}^{n}\left|\frac{x_{ij}-x_{i0}}{\overline{x_i}}\right|} \tag{1}$$

in terms of square standardized distances:

$$SC_s^j = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}\left(\frac{x_{ij}-x_{i0}}{\overline{x_i}}\right)^2 - \sum_{i=1}^{n}\left(\frac{x_{ij}-x_{i0}}{\overline{x_i}}\right)^2}{(m-1)\cdot\sum_{j=1}^{m}\sum_{i=1}^{n}\left(\frac{x_{ij}-x_{i0}}{\overline{x_i}}\right)^2} \tag{2}$$

where:

x_{ij} is the value of the i-th characteristic of the j-th comparable property;
x_{i0} is the value of the i-th characteristic of the subject property;
$\overline{x}_i$ is the value average of the considered characteristic;

m is the number of comparable properties;
n is the number of characteristics.

The reliability coefficient RC^j of a generic comparable j can be defined as follows:

$$RC^j = \frac{\left(1 - \left|\frac{p_j - \overline{p_j}}{\overline{p_j}}\right|\right)^{m+1}}{\sum_{j=1}^{m}\left(1 - \left|\frac{p_j - \overline{p_j}}{\overline{p_j}}\right|\right)^{m+1}} \tag{3}$$

where:

$p_j$is the price per square meter of the j-th comparable property;
$\overline{p_j}$is the average value of the prices per square meter of the considered comparables;
$m$is the number of comparable properties.

To simultaneously consider the similarity between the subject and a generic comparable and the price reliability of this latter one, it is necessary to introduce another coefficient, called the composite coefficient, obtained as a combination of the similarity and reliability coefficients.

The composite coefficient CC^j of a generic comparable j can be defined as follows:

if the similarity coefficient SC^j is calculated in terms of absolute value:

$$CC_a^j = \frac{SC_a^j \cdot RC^j}{\sum_{j=1}^{m} SC_a^j \cdot RC^j} \tag{4}$$

if the similarity coefficient SC^j is calculated in terms of square standardized distances:

$$CC_s^j = \frac{SC_s^j \cdot RC^j}{\sum_{j=1}^{m} SC_s^j \cdot RC^j} \tag{5}$$

where:

SC_a^j—and SC_s^j are the values of the similarity coefficients of the j-th comparable;
RC^j—is the value of the reliability coefficient of the j-th comparable property;
$m$is the number of comparable properties.

The employment of the aforementioned coefficients can assure the selection of *"the best combination of comparable sales"*.

2.2 The Market Segments Comparison Methodology

The application of the market segments comparison methodology can be very useful for appraising the market value of a property located in an area where the number of selling prices of similar properties is low. This methodology involves detecting market data in market segments different from the subject one and then adjusting these data considering the differences between the segments compared. Since, as we mentioned in the beginning, in regard to appraising land, location is undoubtedly the most influential parameter in land market segments, adjustments should particularly concern this parameter.

The market segments comparison methodology consists of the following steps:

detection of the market segment of the property being evaluated;
detection of the comparison market segments;
detection of the real estate prices belonging to the comparison segment or segments;
collection of extra-data of the property being evaluated segment and of the property belonging to the comparison segment or segments;
appraisal of adjustments in percentage terms of the "location" parameter;
correcting the selling prices belonging to market segments other than the subject segment;
formation of the "adjusted" appraisal sample.

In this research, the adjustment of the location parameter is obtained by the use of two extra-data: the average prices of the property, P_j^{OMI} and P_S^{OMI}, obtained from the Observatory of the Real Estate Market (OMI in the Italian acronym) of the Revenue Agency and the coefficients expressing the impact of the land value on the property value, c_j and c_S. Due to the position rent, the values of these coefficients are greater in the central area than in the peripheral area. These coefficients are sometimes reported alongside real estate quotes published by industry organizations.

The extra-data measures must be combined with the data (selling prices of the lands) in terms of their mutual relationship in the following way:

$$\frac{P_{l_j}}{P_{l_S}} = \frac{P_j^{OMI} \cdot c_j}{P_S^{OMI} \cdot c_S} \tag{6}$$

where P_{l_S} indicates the price of the subject land and P_{l_j} is the selling price of similar lands collected in other market segments.

The appraisal of the adjustment Δ_j^{LOC} of the location parameter, expressed in percentage terms, can be carried out by the following expression:

$$\Delta_j^{\text{LOC}} = \frac{P_S^{OMI} \cdot c_s - P_j^{OMI} \cdot \leq c_j}{P_j^{OMI} \cdot c_j} \tag{7}$$

Once the adjustment percentages have been calculated, the corrected market price of the land belonging to a segment different from that on which the subject is located is calculated as follows:

$$P_{l\,j}^{c} = P_{lj} \cdot \left(1 + \Delta_j^{\text{LOC}}\right) \tag{8}$$

A qualitative representation of the above method is shown in Fig. 1.

2.3 The Proposed Land Valuation AVM

The framework of the proposed AVM is shown in Fig. 2. The whole process is operationally based on a GIS environment. In particular, the basic input data pertaining to the land include sales transactions, surface of the lands, and extra-data concerning the real estate markets. Both sales and other data can be managed and explored using appropriate functions available in a GIS, e.g., spatial analysis tools.

The functioning of the GIS-based AVM involves the creation of three thematic layers: the first, called *Sales.shp*, is a point-based feature layer that contains information about

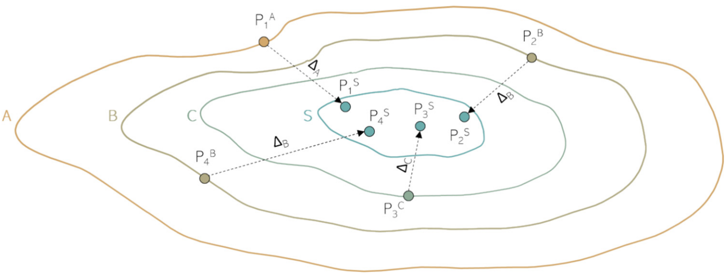

Fig. 1. Qualitative representation of the market segment comparison method.

the similar land collected, such as selling prices and intrinsic characteristics; the second, called *OMI_Zone.shp*, is a polygon-based feature layer representing the territorial area boundaries provided by the Revenue Agency that contains information about the different territorial areas, such as average prices of the specific area and coefficients expressing the impact of the land value on the property value; and the third, called *Subject.shp*, is a point-based feature layer that contains all the known real estate features regarding the land being evaluated (the surface feature is the one utilized in the proposed model).

Generally, AVMs can involve various types of real estate valuation procedures commonly used in real estate appraisals (e.g., deterministic procedures, linear or nonlinear regression, artificial neural networks (ANNs)) [20–24]; in this research, the chosen valuation method is a deterministic procedure, namely, the mono-parametric appraisal procedure.

The AVM initialization input consists of the selection of the selling prices that will be used in the model as comparables to appraise the market value of the subject land. In this regard, the quantity of comparables ought to be sufficient to enable precise characterization of the market; three comparables have been time tested to be an absolute minimum [25]. Data selection occurs through spatial analysis conducted on the thematic layers. Specifically, starting from the position of the point representing the subject land, the polygon of the *OMI_Zone.shp* where this point falls is identified (this polygon represents the market segment of the subject). Then, through a layer intersection operation, the selling prices of the *Sales.shp* that fall within the aforementioned polygon are selected. Depending on the number of data points carried out by the layer intersections, the AVM framework provides three different paths for data processing. Specifically:

If exactly 3 data points are detected, the application of the appraisal method is carried out directly;

If more than 3 data points are detected, the most similar and reliable data points are selected by applying specific coefficients (similarity and reliability coefficients);

If fewer than 3 data points are detected, we have to move on another polygon of the *OMI_Zone.shp,* representing a different market segment than the subject one, and we have to adjust the "nearest data" through a coefficient able to correct the selling prices from the point of view of the localization parameter.

Regardless of which path is followed, the data processing step ends with the application of the mono-parametric appraisal method, which leads to the output of the data, namely, the market value of the subject land.

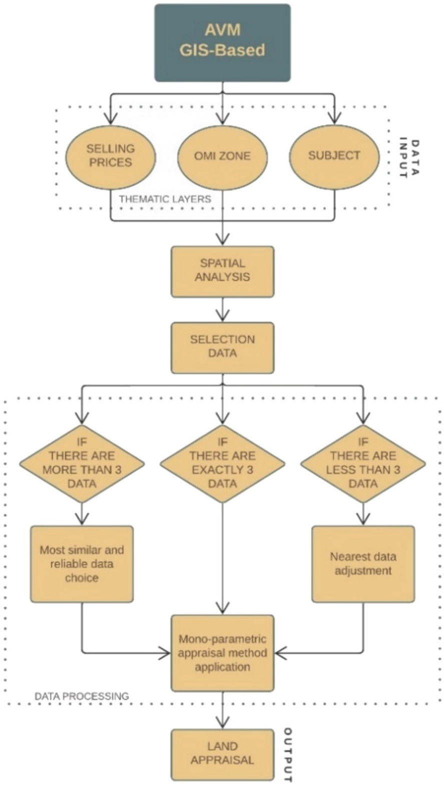

Fig. 2. Land valuation AVM framework in GIS environment.

3 Discussion

The model yields positive outcomes for the land valuation process, which is frequently impacted by the subjectivism of the individual who appraises a land, resulting in numerous difficulties in the field. The development of publicly accessible real estate databases can make a significant contribution to enhancing the applicability of the proposed procedure (this is necessary to build the thematic layers of the GIS-based model). During the last period, some experience with this topic, such as that of *Geocomparabili*, has taken place in the Italian context. This Web GIS service[1] is a result of the collaboration

[1] The goal of this Web GIS service is to promote the growth of a shared real estate database that supports real estate evaluators in their daily professional activities and facilitates the retrieval of property market data. The database currently only supports residential and commercial types

between Geoweb S.p.A. and the Italian Institute of Resources for Economic Development (IIRSE*). Its availability through the platform *Comparabilitalia.it* facilitates the accessibility of market data and information essential for the preparation of real estate valuation reports, in accordance with the applicable national and international valuation methodologies and standards, as mandated by the relevant regulations.

In accordance with international valuation standards, the proposed model presents a well-defined and transparent operational protocol, allowing third parties to review the results and control the steps. The model effectively replicates, through the utilization of IT tools, the estimation procedure that facilitates the identification of comparison buildings based on logical criteria (belonging to the same market segment) and geographical criteria (proximity to the property being estimated), while simultaneously utilizing simple mathematical operations on the data. Due to these qualities, the proposed GIS-*based* AVM can be very useful for valuation purposes, and it can help public administrations make decisions about their projects and support the quantification of the tax amounts, for instance. Furthermore, the proposed procedure has the advantage of being extensible and adjustable to specific situations, provided that the databases have the same structure, in terms of thematic layer design, as the one suggested.

4 Conclusions

The availability of GIS technology in different disciplines provides updatable, accessible, and analytical solution opportunities for determining the value of real estate [26]. The diffusion of Web GIS services that build publicly accessible real estate databases is helping to increase these new opportunities in the Italian context. Within this framework, the proposed GIS automated model in the current article can offer an excellent solution for the assessment of land prices and their evolution within the real estate market.

It is known that real estate evaluation is a critical profession that is applied for public needs such as tax calculations, expropriation, and land arrangements, as well as private sector requirements such as insurance business and banking. For the aforementioned practical purposes, this research can be very useful. Specifically, the proposed model may have full practical implementation in Italy and in other countries, helping appraisers assess land market value according to international appraisal standards. Moreover, the model has the potential to provide significant assistance in the quantification of yearly taxation in the Italian context, specifically the quantification of a single municipal tax, commonly referred to as “Imposta Municipale Unica” or IMU. The amount of this tax is determined by the market value of land classified as “buildable” by the general urban planning instrument.

Although the research is at an earlier stage, the model can be utilized to facilitate real estate appraisal activities by considering market data, particularly in situations where the absence of selling prices renders assessment more challenging.

Future insights from this research could consist of enriching the model by considering not only surface features but also other parameters measurable with the spatial analysis tools provided by the GIS system. By utilizing this approach, the GIS-*based* AVM can

of real estate, but it would be interesting to extend the service to other types of real estate, such as land.

involve a multiparameter real estate valuation procedure with greater performance than the mono-parametric procedure employed in this study.

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Blockchain Technologies for Supply Chain Logistics Management. The Risk of Creating a False Myth with Negative Consequences for Local Development

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Abstract. Although Information Technology has always played a strategic role in business management, its importance has evolved significantly in recent years, reflecting the progressive transformation of manufacturing environments and the consequent growth in the complexity of interdependent functions related to the logistics management of global supply chains. In this key field of world trade, in addition to the relevance of Big Data, the use of Blockchain technology is becoming increasingly widespread. Access to this technology, in addition to offering benefits, is often a prerequisite for a supplier to be part of a supply chain. However, the disintermediation and lack of third-party control implicit in this technology may allow large companies to have a binding influence on production standards and choice options for possible repositioning of suppliers, in search of higher value-added shares within a supply chain, as well as the spatial distribution of production activities, negatively affecting the development processes of specific territories.

Keywords: Blockchain · Logistics · Supply Chain · Local Development

1 Introduction

This article aims to discuss the growing importance of Information Technology (IT) in Logistics of Supply Chain Management (SCM) and is based on the secondary analysis of survey data conducted by Istat using the Digital Competence Framework 2.0 methodology and DESI, Digital Economy and Society Index activated by the European Commission since 2014. The discussion has two main objectives: the first is to show how the technological gap between Italian regions pushes SMEs to rely on technologies managed by large companies and platforms; the second objective is to briefly show how Blockchain technology is not the safest way to avoid widening gaps between companies and disadvantaged territories, in Global Value Chains (GVC), without a consolidated and institutionalised system of third-party controls.

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2 Argument: Logistics Matter(S)

The polysemic word 'logistics' indicates a technique, an art of computation: the computation of the mobility of people, material and immaterial goods; in market economies, which could not function without the capacity of transport to connect supply and demand. According to the definition in the glossary published by the *Council of Supply Chain Management Professionals* [1], logistics is in fact "the process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements. This definition includes inbound, outbound, internal, and external movements".

However, according to a report by the *Commission on Trade in Goods and Services and Commodities* [2], there is no clear definition of what would constitute logistics services, as it is difficult to draw a dividing line between these and other sectors, such as transport services, which are included in Supply Chain Management (SCM) as a key activity dominating the evolution of the trade. In fact, with varying degrees, the function of logistics encompasses a broad set of activities dedicated to the processing and distribution of goods: from the procurement of raw materials, transport, warehousing and various related value-added services (such as labelling, packaging and inspection services), customer service, to the distribution of goods and the recall of defective products from the end market.

Logistics is consequently a logic of planning and organising aimed at ensuring that certain resources are in the places where they are needed so that an activity or process can be carried out efficiently. Logistics management is therefore involved in all levels of planning and execution: strategic, operational and tactical; and is a function that coordinates and optimises all activities, integrating them with other functions, including marketing, sales, production, finance and IT. In addition to these aspects, the concept of *Supply Chain and Logistics Management* also includes financial and information flows, customer relations and customer satisfaction, making supply chain logistics functions of activities more integrated and complex [3, p. 270].

It therefore follows that the interaction of logistics, as well as SCM, with local and global trade, cannot be considered separately. A holistic analysis of the logistics process cannot be limited to the study of management and the analysis of cost functions but requires a rethinking of some of the key concepts with which we understand modern production systems and the related social formations dispersed in a geographically extensive and interconnected space. This space is not related to discrete segments of supply chains but to the *logistical space* and to the logic that has transformed the relationship between production and circulation that characterised the apex of industrial capitalism, whereby it is misleading to think of a single place where goods are produced. Today, goods are produced throughout the logistical space of GVCs, rather than in a single location. This paradigmatic space of logistics is the supply chain network, which consists of infrastructures, information, goods, equipment, means of transport and people, and is defined by the assembly of these heterogeneous socio-material flows [4–6].

Logistics, according to this interpretation, has consequently become much more than just a techno-science of SCM: it is the main vector of the integration of the global economic space [7], a constantly updating discipline whose boundaries are continuously redefined by the evolution of needs and practices, moving on the frontier between social and technological innovation, often being the architect. This logic, on the one hand, tends to make the world smooth and frictionless, to facilitate an ever-faster circulation of flows of materials, information and finance, profoundly influencing transformations and territorial arrangements in the various degrees of the scale from global to local; on the other hand, it does not remove the legal and economic gaps that allow supply chains to exploit and extract value through spatial and juridical differentials, through the acceleration and capacity of the means of transport of tangible and intangible goods, and through a highly unequal international division of labour [5, 8]. In fact, logistics unifies spatially separated production and distribution processes through integrated intermodal systems, so that labour sectors that are geographically unconnected are reunited only by the global role of a few companies on a scale never seen before historically [5, 9]. Logistics is in essence the geographical form of the economy.

With these definitions, it can be clearly deduced that a vital element for logistics business and SCM, apart from technology, is information [10, 11]. Indeed, information is not only the lifeblood of accounting, but also the main source of managerial decision-making processes, which are highly dependent on the quality, accuracy and promptness of information. Information is the meaning that is extracted from data which, in turn, constitutes the elementary description of events or activities that are recorded [12]. In other words, data can be compared to a raw material that acquires value when it is transformed into a final product, or information. It is therefore understandable why the use of big data and blockchain technologies is becoming increasingly widespread in logistics for SCM. Data management and analysis, the most obvious symbol of which is the now ubiquitous QR code, is in fact the 'kitchen secret' of the most important companies operating in the transnational chains of the so-called Industry 4.0, Internet of Things (IoT), Smart Automation and Web3. This increasingly strategic interest in the management of big data has also created its own field of studies called Business Intelligence & Analytics, public and private research centres and think tanks, which deals with techniques, technologies, systems, practices, methodologies and applications that generate and analyse strategic data [13] with the aim of directly or indirectly enabling the management of companies to better understand their business and make timely decisions.

However, despite the theoretical enthusiasm for these innovations, it should also be emphasised that the spread of privatisation of these data, and blockchain technology, itself is making the data increasingly inaccessible to stakeholders and researchers, causing information asymmetry and a lack of transparency, with the risk of consequent trust issues and difficulties for producers and consumers in obtaining reliable and authentic product information [14, 15]. These pitfalls, if not correctly identified and effectively countered, also risk reinforcing the tendencies towards economic and territorial polarisation at different scales in the global space, often linked to activities with a high innovative content, contributing to the increase in the social divide, the production of new geographies of inequalities, the formation and reinforcement of processes of exclusion, new centre-periphery dialectics and marginalisation of territories 'left behind' or 'that don't matter'.

3 A Digital Divide to Be Bridged in 2030

According to Istat surveys, conducted using the methodology of the Digital Competence Framework 2.0 [16], the common European framework of reference for digital competences, Italy ranks fourth to last in Europe in digital basic skills. With a European average of 53.9%, at the bottom of the ranking are Italy (45.7%), Poland (42.9%), Bulgaria (31.2%) and Romania (27.8%); leading the ranking are Finland (79.2%) and the Netherlands (78.9%), which already have values almost in line with the 2030 target of 80%. Regarding the gaps between Italian regions, the strong differential in digital competences between the Italian regions of the Centre-North and the South is evident. While regions such as Lazio (52.9%), Friuli-Venezia Giulia (52.3%) and the Autonomous Province of Trento (51.7%) are close to the European average, others such as Campania (34.2%), Sicily (34%), and Calabria (33.8%) lag far behind.

The monitoring provided by the European Commission's Strategic Programme for the Digital Transition, regarding the percentage of enterprises that provide Information and Communication Technologies (ICT) training to their employees, also shows limited specialised digital skills in small and medium-sized enterprises (SMEs). Eurostat's "Survey on ICT in Enterprises" estimates that, in 2022, only 13.4% of enterprises with at least 10 employees had hired ICT experts, 4.9% tried to hire such experts or employed them in the previous year, and 19.3% provided training courses in the previous year to develop or update the ICT skills of their employees. The employment of ICT specialists has remained stable compared to 2020, confirming the reduced use of these figures by Italian companies when compared to the European average (21%). In this ranking, Italy is significantly behind Germany (22.2%), France (17.6%) and Spain (16.3%). At the size level, there are important gaps among enterprises with between 10 and 249 employees (SMEs) and larger enterprises (with at least 250 employees) in terms of both the adoption of specialists (12.2% and 75% respectively) and the decision to invest in ICT training during the previous year (18.4% versus 65.4%). 57.2% of Italian SMEs declared that they use exclusively external suppliers for the management of ICT functions (45.6% the EU27 average), compared to 14.2% of large enterprises (10.9% EU27) [16].

In relation to the economic activities carried out (Fig. 1), the best performances are recorded by the enterprises belonging to the specialised and strategic ICT demand sector: telecommunication services (72.4% employed and 60.4% in the organisation of training) and IT (65.2% and 56.0%) stand out above all, followed by computer manufacturing (39.5% and 32.8%) and publishing (35.3% and 32.8%). The employment of ICT professionals concerns at least 1/4 enterprises in the postal services sector, in the manufacture of means of transport and electrical equipment. On the other hand, ICT professional training affected about 1/4 of the enterprises in the professional sector, coke manufacturing, energy supply and waste management [16].

Another survey [17], conducted in 2022 with respect to 12 specific characteristics that contribute to the definition of the composite digitisation indicator called Digital Intensity Index (DII)[1] [18, 19], by class of employees, showed large gaps to the detriment of SMEs, in employment of ICT specialists, in relation to the decision to invest in ICT training

[1] The DII, referring to SMEs with a 'basic' DII level, is one of the sub-indicators of the digital transition of enterprises as measured by the DESI, Digital Economy and Society Index, activated

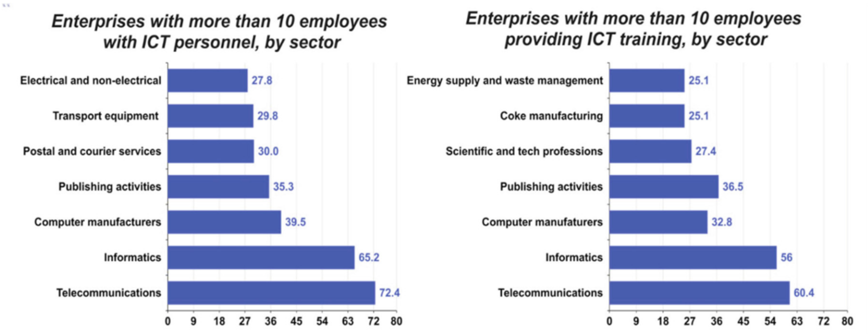

Fig. 1. Source: Istat-Eurostat, Community Survey on ICT usage in Italian enterprises.

during the previous year, in the use of online meetings and specialised documentation on the rules and measures to be followed in IT security. Significant disparities were also indicated in the use of robots and online sales of at least 1% of total turnover, which significantly reduces the overall percentage of enterprises with at least 10 employees using these devices and equipment. In 2022, 69.9% of SMEs were at a basic level of digitisation, i.e. adopting at least 4 out of 12 digital activities, but only 26.8% were at defined high levels of the indicator. On the contrary, 97.1% of the enterprises with more than 250 employees had at least a basic level while 82.1% reached the high level [17].

Regarding the economic activities performed by the Italian enterprises, for most of the indicators of ICT connectivity, security and training; the best performance is recorded by enterprises belonging to the specialised and strategic ICT demand sector, such as that related to energy supply, in which 86.4% of enterprises have at least 50% of their employees accessing the Internet (the average is 49.3%), 93.3% have activated at least three ICT security measures (about 20% points higher than the average) and 38.3% have provided ICT training to their employees (19.3% enterprises 10 +). The performance of the technical professions and information and communication services sectors was similar. The latter stand out for the presence of ICT specialists (59.9% against an average of 13.4%) and the training carried out to update or develop the ICT skills of their employees (52.5% against 19.3%). Finally, manufacturing activities stand out for their use of robotics (19.1% against an average of 8.7%), while with 36.8% accommodation, food service and catering activities are the first for the use of online sales for values of more than 1% of total turnover against 13.4% of enterprises with at least 10 employees [17].

With respect to the digital technology integration dimension, improvements in cloud services and e-invoicing in recent years have put Italy now ranking 7th among European countries. However, the limited performance of e-commerce by SMEs has reduced the growth effects of digital technologies measured in 2020 and 2021. The 2022 data for online sales by SMEs did not reveal significant improvements in the share of companies involved, but only in the value traded: 13% of SMEs made online sales of at least 1% of

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by the European Commission since 2014, to which the 'Digital Compass 2030' programme has also given a target (90%) to be reached by 2030 (Table 1).

Table 1. Source: Istat-Report on ICT in Italian enterprises. Year 2022

	Enterprises by level of digitisation				Enterprises with a basic *level* of digitisation	*Employees of enterprises with basic level of digitisation (% of total employees)*
	very low	low	high	very high		
	GEOGRAPHICAL DISTRIBUTION					
North-West	26,0	41,7	29,3	3,1	74,0	91,3
North-East	27,4	43,1	26,1	3,4	72,6	88,8
Central Italy	33,9	42,8	21,1	2,2	66,1	85,0
South and islands	33,4	43,3	21,2	2,2	66,6	76,7
	CLASSES OF EMPLOYEES					
10-49	32,5	44,4	21,8	1,4	67,5	70,8
50-99	12,1	37,2	44,7	5,9	87,9	88,4
100-249	7,2	25,2	52,7	15,0	92,8	93,4
250 and more	2,9	15,0	49,8	32,3	97,1	98,7

total revenues (12.7% in 2021) and 17.7% of SMEs active in e-commerce made 13.5% of total revenues online (17.9% and 9.4% in 2021, respectively). Overall, 18.3% of enterprises with at least 10 employees made online sales accounting for 17.8% of total turnover, respectively 22.8% and 17.6% at EU27 level [17].

In terms of composition, the value of online sales is realised mainly in the trade sector (35.6%), in the manufacturing sector (28%, with a predominance of automotive-related activities), and a similar share in the energy sector. In terms of size, 60% of the online value comes from sales by larger companies and 40% from SMEs. In the composition of enterprises selling online, apart from the energy sector where few enterprises are present, the food service, catering and accommodation sectors stand out, covering more than a third (35%) of all enterprises active in e-commerce. 95.1% belong to the SME size. Italian companies with at least 10 employees selling via the web are still among the top users in Europe of online platforms as intermediaries with 62.1% against an EU27 average of 44.4% [19]. For these reasons, Italy's "PNRR" recovery and resilience plan (RRF of Next Generation EU) allocated 25.1% of the total amount (i.e. EUR 48 billion out of EUR 191.5 billion) to digital transition.

4 A Technology for the Cybernetic Control of Supply Chains

The word Blockchain is generically associated, often erroneously, with digital crypto currencies, such as Bitcoin, whose invention is traced back to Satoshi Nakamoto, a pseudonym whose real identity has never been revealed. Under Nakamoto's name, the website bitcoin.org was registered in August 2008 and a nine-page document was published shortly afterwards. This publication described the functioning of a peer-to-peer (P2P) system that allowed the transfer of digital currency without passing through the control of any financial institution. A year later, the first version of the Bitcoin software was born, at the same time as the network that served as a ledger, giving birth to the now legendary bitcoin genesis block number 0. However, blockchain technology (BT) was not invented by Nakamoto, whoever he may be, and by the second BT generation its purposes go far beyond the possibility that it could only give rise to a secure and globally recognised digital currency for all transactions, although the very fact that it was conceived for the disintermediated transactions of a digital currency such as Bitcoin has strongly characterised its path dependence.

To summarise, BT essentially comprises a decentralised network of P2P transactions and transfers, i.e. it allows actors to enter a direct relationship with each other, based on a set of rules established and shared (in theory) between users, without a central authority or intermediary, combining data science and cryptography in a new governance model [20]. Computers in the network (the nodes) manage the same data sets using encrypted algorithms, called 'cryptographic hashes', i.e. they assign a fixed-length character string to an input, which constitutes the digital fingerprint of a document to which a collateral corresponds. Transactions are carried out through protocols called *Smart contracts*, which confirm them, encoding them in 'blocks'. The chains of these blocks, which cannot be changed without consent, then form a digital record of transactions that functions like a ledger. Records of property transactions (assets and their values) are stored permanently in the ledger, due to the existence of multiple identical copies, equal to the number of connected nodes in the blockchain [20–23]. This makes manipulation of information extremely difficult, giving blockchains a high level of security, thus making them a strong alternative to traditional centralised databases in technology platforms. The principle underpinning the functioning of a blockchain, better known as *Distributed Ledger Technology* (DLT), is the Proof-of-Work (PoW) consensus algorithm, introduced since the first generation to check and verify the accuracy of a transaction, and is based on the chronological chain of data that are ordered in specific structures, relating to the sources of digital and physical assets. This principle dates to the work of two cryptographers, Stuart Haber and Scott Stornetta, who developed it in 1991. On the other hand, it was Nick Szabo, a computer engineer and cryptographer, who first conceptualised *smart contracts*, which, according to his definition, are codes or protocols stored on a blockchain, i.e. programmes that are executed automatically when certain pre-established conditions are complied.

Smart contracts are in fact contractual agreements that auto-execute on blockchain platforms so that all participants involved can be immediately certain of the outcome, saving time and eliminating any costs associated with mediation [24]. These protocols can also automate a workflow, functioning as a cybernetic command, triggering the next action when certain conditions are realised, without the need for a recognised and trusted central authority or third party to control the process [25]. It is precisely smart contracts, which are beginning to be complemented by Artificial Intelligence (AI) systems, that are considered the main cybernetic innovation that has opened the doors of BT to industrial uses [21] particularly in the management of SCM operations [14, 26]. A key role in the efficient functioning of smart contracts in BT for SCM is played by oracles (Fig. 2). These are procedures, such as application programming interfaces (APIs), but they can also have other methods and modalities, not least of which is the possibility that they are inputs entered by real people, linking the blockchain to external off-chain systems, thus enabling the execution of smart contracts on the inputs and outputs from the real world for which they were set up. Without oracles, smart contracts would have no interaction with real-world phenomena, making blockchains unverifiable and blind. Users can only understand what is happening to a blockchain, in any given functionality of a BT, and maintain control of their assets at all times, through the correct functioning of oracles.

BT adds value to SCM by offering a reliable and rapid method of authentication and traceability for all stages of the production process, recording the acquisition of raw materials, and all the processing that is performed throughout the production and the transport chain of goods, up to the finished product, including the verification of logistical distances, adherence to laws on driving and customs regulations. In this way, BT should be able to tackle fraud, theft, loss and the systematic inefficiencies that drive up shipping and SCM costs.

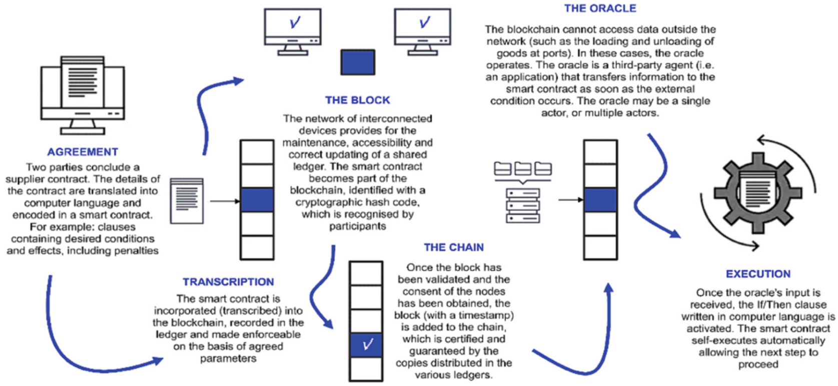

Fig. 2. Example of smart contracts functioning

Through these algorithms, BT can enable companies to track, trace and verify how goods transit and move along a supply chain, from manufacturers to retailers via distribution centres and logistics facilities, thus limiting the need for intermediaries to verify or transfer ownership rights [27]. There would be many reasons to believe that this technology is the most transformative since the creation of the World Wide Web, as it is based on the principle of consensus and 'disintermediated' trust. In truth, things are not as simple as they seem.

5 Question: An Asymmetric Business Relationships?

BT promises a transformative effect on logistics and SCM by improving the flow of information between partners. However, the introduction of this technology currently requires extensive technical preparation and, ideally, interaction with digital twins at every stage of the process. But how is it used?

Research conducted using qualitative techniques [26] showed that enterprises and companies that had adopted this technology used it for different purposes. A first aim was to use BT as a lever to guide the digital transformation of the company. A second aim included BT as a new type of management in products or services capable of developing solutions for new business models or rules of inclusion in the SCM. A third was to join or found a blockchain consortium to unify the industry and establish standards.

Other studies [14] have found, however, that the concrete use of BT is only one of the ways to manage a supply chain and that it is not the most widespread. Among various reasons, companies often lack the digital knowledge necessary to implement BT and integrate it into their business processes, given the insufficient resources available for workforce training and access to the necessary digital tools. Other resistance to the use of BT concerns obstacles related to the newness and immaturity of the technology, long-term uncertainties related to possible changes in regulation, and the lack of opportunities to learn from established real practices well-designed and monitored. It was observed, in fact, that actual implementations of BT in the SCM and Logistics field would need an open ecosystem and not be driven by large companies interested in building the infrastructure. Holding companies back from adopting this technology are also problems related to its technical usability, which is still complicated due to the lack of ready-to-use interfaces and easy-to-use solutions for consumers [26].

Smart contracts are not an optimal solution for all supply chains, and there are several issues that limit their adoption (for example, legal and privacy issues, lack of standards and protocols, coding issues and even performance). Furthermore, not insignificant problems also concern the security of BT, i.e. the aspect that should constitute their element of greatest interest. In theory, a code of law or any regulation can be incorporated into the code of a smart contract in a blockchain, making breaking the law equivalent to breaking the code. However, this does not exclude that to violate the law it is sufficient to 'crack' the computer code [21]. In fact, the simple use of encryption does not constitute a guarantee that transactions will be secure. In addition to the risk of hacker attacks on consensus algorithms, i.e. the set of instructions that guarantee that the blocks are all correct; there is also the problem of vulnerability to attacks conducted to sabotage the correct execution of smart contracts, such as the so-called 'oracle manipulation', with which information external to the blockchain is surreptitiously modified, for example by manipulating the flow of variation data of a certain asset, or the transit data of a container of goods, etc. [28]. A further problem concerns the asymmetric relationship that is established through private BT, when the network is ego-centered on a node that represents a large global company. To avoid the risk of reputational damage, big companies often find themselves in the position of having to ensure that their suppliers, scattered across the peripheries of the planet, respect company codes of conduct, at the same time preventing incorrect behavior from environmental and social point of views. In relationships with globally dispersed suppliers, big companies have often preferred monitoring mechanisms to verify suppliers' compliance with selected sustainability standards, rather than costly forms of collaboration. Monitoring mechanisms usually include the establishment of sustainability standards, evaluation routines and the adoption of devices and systems to monitor the suppliers. These can include sanctions, such as exclusion from the supplier network, in the event of non-compliance. In truth, what happens is that the monitoring mechanisms are often accompanied by the unilateral imposition of standards and objectives by the buying company. In most cases, sustainability standards are defined only by big global companies and imposed on suppliers in emerging countries. However, it is the very concept of "transparency" that is problematic in a GVC [29]. As proof of the persistence of this problem, to give just one example, the *Clean Clothes Campaign*, the largest alliance of trade unions and NGOs for the improvement of working conditions in the clothing industry, recently wrote an open letter to the Presidency of the Council of the EU, signed by over 90 organizations from the Global South, to support the adoption of effective regulations on due diligence, to combat the indiscriminate exploitation of the workforce and guarantee access to justice, to avoid activities production processes that are harmful to the environment and for the recognition of the role of trade unions in the global contexts in which companies operate [30].

Perhaps we should ask ourselves to what extent BT, in this or other sectors, can really allow more transparent SCMs and protect the rights of workers, consumers, trade unions and supplying companies themselves, to avoid distortions. Traceability is a tool for tracking the steps in a chain, but it does not guarantee the actual origin of raw materials, or components, when they are introduced into the value chain. Given that the very access to a blockchain, where this technology is used, is the main condition to enter the network of suppliers, the absence of consolidated forms of control and external institutional monitoring risks to provide global corporations with a strong tool to impose standards on enterprises located in disadvantaged areas, or on the periphery of the global South, exploiting the invisibility of the mechanisms induced by BT. In fact, this was created to guarantee a digital currency free from institutional financial intermediation, but what about SCM? Is it appropriate to limit the monitoring tools of third-party bodies, leaving all the power of control to the big companies that manage the network thanks to the strength of their brands? Who controls the controller?

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Green Infrastructures, Pollutant Absorption and Economic Values

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Abstract. The environment, the climate emergency and the challenge of nature conservation and biodiversity are crucial issues. In urban areas, where the effects of climate change and the increase in pollutants are most pronounced, the Ecosystem Services offered by greenery, such as the removal of air pollutants, the absorption and sequestration of CO_2 and the mitigation of high urban temperatures, produce significant benefits for communities.

This research focuses on the ability of green infrastructure to reduce concentrations of dangerous air pollutants, namely Particulate Matter (PM) and ground-level ozone. First, the mechanisms of the uptake of both PM and ozone by vegetation are investigated, highlighting their effects on human health. Then, a critical review of the main approaches to estimating economic costs and benefits related to the change in mortality and morbidity caused by air pollution is proposed. Finally, on the basis of literature data, an indicative value of the economic benefit for Italy related to fewer deaths due to improved air quality is suggested.

The perspective of the paper is the definition of a model capable of correlating the levels of particulate matter and ozone absorbed annually by vegetation with the monetary value of the corresponding ecosystem service. This is done by estimating both the reduced health costs resulting from the reduction of diseases and the economic benefits resulting from the reduced number of deaths.

Keywords: Green infrastructure · Ecosystem Services · Air pollution · Health effect · Economic costs

1 Introduction and Purpose of the Work

In the context of climate change, urbanisation and globalisation, the challenge of conserving nature and biodiversity worldwide is of paramount importance. In cities, where more than half of the world's population lives, the effects of climate change and the increase in pollutants are most apparent. The process of urbanisation, which has affected and continues to affect all continents, entails significant modifications of the natural environment, with both direct and indirect effects on people's health. One of the greatest challenges worldwide is the protection of public health, which is severely threatened by human impact [1].

(*) All Authors contributed equally to this work.

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Current population growth, climate change and the resulting increase in pollution levels raise several issues related to both human health and the state of natural and anthropized ecosystems. From this perspective, it is particularly important to quantify and conserve Ecosystem Services (ES), that is the benefits provided by an ecosystem, whether natural or man-made. ES are directly and indirectly related to well-being and quality of life [2]. They are intrinsically linked to spatiality and thus to the territory [3], to whose inhabitants they provide irreplaceable benefits, directly or indirectly, because of interactions between ecological, social, and cultural processes.

The Millennium Ecosystem Assessment (MEA, 2005) identified four categories of ES: (i) provisioning, i.e. goods that can be harvested, traded, consumed, or used directly from ecosystems, such as food, raw materials, fresh water; (ii) regulating, i.e. physical, ecological and biological processes that are fundamental to ensuring the integrity of ecosystems. These services include the purification of air and water, the provision of fertile soil, the control and regulation of hydrological and biological cycles, the management of natural hazards, the removal of pollutants, the absorption of CO_2 and the mitigation of climate change; (iii) cultural, related to the intangible benefits provided to humans, such as artistic inspiration, spirituality, cultural heritage and landscape; (iv) supporting, i.e. necessary for the realisation of all other services, such as photosynthesis, pollination, soil formation and many other natural mechanisms [2].

The concept of ecosystem services highlights the need to consider the preservation and enhancement of the natural components of the urban environment as fundamental elements of an urban development concept, as they are a *condicio sine qua non* for the very existence of society [3].

For this reason, especially for planning purposes [4], it is useful to understand ecosystem services as an interpretative paradigm, and not as a natural component, which allows for monetary and non-monetary valuations and mapping of environmental and territorial assets [5], representing one of the keys to the implementation of European and international sustainable growth policies [6].

In urban areas, the regulating services provided by urban greenery, such as the removal of atmospheric pollutants (e.g. particulate matter and tropospheric ozone), the absorption and sequestration of CO_2 and the mitigation of high urban temperatures, play a very important role with multiple practical and functional implications, from energy saving to improving the quality of life.

This paper aims firstly to analyse the regulatory services provided by urban greenery and to link the annual amounts of particulate matter and ozone absorbed by vegetation to positive effects on human health. It then reviews the methods used to estimate the impact of pollution on human health, both in terms of mortality and morbidity. Finally, based on literature data, a rough estimate is made of the economic benefits for Italy associated with fewer deaths due to improved air quality.

The paper is divided into the following sections. Section 2 deals with the capacity of green infrastructure to absorb the main air pollutants, i.e. PM and ozone. Section 3 discusses the effects of PM and ozone on human health through a summary of the main literature studies investigating the relationship between air pollution and mortality/harm to human health. Section 4 critically reviews the main approaches to estimating the benefits/costs associated with a change in mortality/morbidity caused by a change in air pollution. Finally, Sect. 5 presents the conclusions of the work and highlights research perspectives.

2 Green Infrastructures for the Absorption of Particulate Matter and Ozone

Green infrastructure is not only aesthetically pleasing, but also helps to mitigate pollution and the negative effects of climate change. Urban and peri-urban vegetation is an important resource for the sustainability of systems, as it enables:

a. the reduction of noise levels caused by human activities;
b. mitigating the effects of solar radiation to help reduce urban heat islands;
c. reducing air pollution and improving air quality. This is one of the most studied ecosystem services and one of the most important in terms of human health and well-being. Indeed, air pollution is associated with an increased incidence of pulmonary and cardiovascular diseases, neurological disorders, and cancers, according to a classification by the International Agency for Research on Cancer (IARC) in Lyon [7].

This research focuses on the ability of green infrastructure to reduce concentrations of hazardous air pollutants, namely particulate matter and ground-level ozone. The mechanisms of uptake of both PM and ozone by vegetation are outlined below.

2.1 Atmospheric Particulate Matter

Atmospheric particulate matter is a complex mixture of solid and liquid, organic and inorganic particles suspended in the air, commonly referred to as PM followed by a number indicating the particle diameter. The constituent particles can be grouped according to how they are emitted into the atmosphere. Some are called primary particles if they are emitted directly from the source into the atmosphere, as in the case of combustion or road traffic. Others are the result of chemical reactions that take place in the atmosphere between primary particles and other elements. PM can also come from natural sources, including, for example: mineral particles, marine aerosol emitted from the sea surface and volcanic eruptions. However, PM is mainly associated with anthropogenic sources, which can be traced back to the energy and transport sectors, the industrial sector and the whole food chain [8]. The construction sector is another major contributor to the release of particulate matter into the atmosphere, resulting from the generation of dust throughout the life cycle of buildings [9, 10].

The concentration of PM is influenced by multiple and complex physical-chemical, environmental and spatial factors, such as distance and height of the emission source, land conformation and use, but also the microclimatic conditions present, mainly wind direction and intensity, humidity, rain and snowfall. The mechanisms by which plant species can affect PM concentrations can be grouped into different processes:

the first is uptake/adsorption by direct contact of the pollutant by the plant, with the leaves trapping a variable amount of PM depending on the characteristics of the leaves

themselves (presence of hairs, resins, secretions, waxes, etc.) and the location, structure, shape and type of the leaves. Particulate matter remains deposited on plant surfaces until a meteorological event, such as rain or wind, washes it away or re-suspends it in the atmosphere;
the second process is aerodynamic and is determined by the interactions between the turbulent air currents that transport the particles and the structures of the plant. These intercept and modify the flow of pollutants through the foliage and branches, improving their dispersion in the atmosphere or their diffusion in neighbouring areas.

The ability of trees to remove pollutants varies according to season and leaf characteristics. Evergreen species can interact with PM even in winter, when concentrations are higher due to the heating of buildings. In addition, the needle-like shape of conifer leaves is more efficient at trapping particulates [11].

2.2 Ozone

Tropospheric ozone is a secondary pollutant. This means that it is not emitted directly into the atmosphere, but is formed when some primary pollutants, particularly nitrogen oxides and volatile organic compounds, undergo photochemical reactions in the presence of solar radiation and high temperatures. In the stratosphere, ozone shields ultraviolet radiation from the sun, preventing it from causing damage to human health. However, in the lower layer of the atmosphere, it becomes extremely reactive, triggering membrane oxidation reactions and cellular damage, leading to cell death (necrosis) or impaired lung function and respiratory inflammation. Due to the strong dependence on solar radiation and high temperatures, the concentration of ozone in the lower troposphere is generally higher during the summer period; for the same reason, southern European countries are more exposed to ozone pollution than northern countries [10].

As reported in several studies, plants can absorb tropospheric ozone through stomatal openings and also to remove it from the troposphere through deposition processes [8]. The presence of trees therefore has an important influence on ozone levels in the atmosphere, not only because they help to reduce local temperatures and thus change the reaction rates of chemical formation, but also because the ozone deposited on their leaves diffuses into intercellular spaces and dissolves in aqueous films [10].

3 The Effects of Particulate Matter and Ozone on Human Health

Air pollution poses a significant threat to public health, ranking as the fourth leading global risk factor for death in 2019 and causing almost 7 million deaths, 213 million Years of healthy Life Lost (YLL) and a reduction in life expectancy of 20 months [12].

PM and Ozone (O_3) are among the most studied atmospheric pollutants, both for their harmful impact and for their high levels recorded in several countries [13, 14]. PM includes multiple components and size fractions: PM_{10}, consisting of both fine ($PM_{2.5}$) and coarse ($PM_{10-2.5}$) particles, is largely composed of crustal material, sea salt and biological material, while $PM_{2.5}$ consists of components with dimensions of 2.5 microns or less and derives mainly from combustion sources. Ozone is a secondary pollutant, as it is formed by the photochemical reaction of other pollutants [15].

In 2021, the World Health Organisation updated its guidelines on outdoor air pollution levels, initially established in 2005. These guidelines provide proven standards for specific air pollutants that cities should adopt as air quality targets. According to the document: annual average concentrations of $PM_{2.5}$ must not exceed 5 $\mu g/m^3$, while 24-h average exposures must not exceed 15 $\mu g/m^2$ for more than 3–4 days per year; for PM_{10}, concentrations of 15 $\mu g/m^3$ annual mean, 45 $\mu g/m^3$ 24-h mean; for Ozone (O_3), concentrations of 100 $\mu g/m^3$ 8-h mean [16]. Epidemiological, clinical, and toxicological studies systematically document a wide range of adverse health outcomes caused by PM and ozone, ranging from respiratory symptoms to mortality from cardio-pulmonary diseases and lung cancer. These effects result from both short-term and long-term exposure to air pollutants at levels usually experienced by urban populations around the world, in both developed and developing countries.

As for short-term exposure to air pollution, this is shown to be linked to higher rates of both hospitalisation [17, 18] and mortality [19, 20]. An extremely interesting result is that of Pappin et al. [20], who show that despite the improvement in air quality in some nations following the WHO's [2018] target standards, positive and statistically significant relationships persist between air pollution and hospitalisation and mortality from all causes (cardiovascular disease, respiratory disease and lung cancer). This result shows that no threshold below which exposure can be considered safe can be defined. Multiple meta-analyses have been conducted to assess the correlations between short-term exposures to air pollution and mortality. To name just a few, Yan et al. [21] estimate that for a 10 $\mu g/m^3$ increase in the 8-h mean maximum ozone concentration, the percentage change for non-accidental mortality, cardiovascular mortality and respiratory mortality are 0.42%, 0.44% and 0.50%, respectively. Sui et al. (2021) [22] explore the short-term impacts of $PM_{2.5}$ and O_3 on death in Hefei (China) from 2013 to 2018, showing that a 10 μ/m^3 increase in $PM_{2.5}$ leads to a 0.53% increase in mortality for non-accidental diseases, 0.93% for cardiovascular diseases, and 0.90% for respiratory problems.

Analyses in 28 EU countries show that despite significant reductions in emissions, the urban population was exposed to levels of $PM_{2.5}$ and O_3 well above the WHO limit values. In each case, the annual number of $PM_{2.5}$-related deaths decreased by 4.85 per 106 inhabitants, in line with the reduction in fine particulate matter levels; whereas, the increase in ozone led to an increase in the annual number of O_3-related premature deaths of 4.85 per 106 inhabitants [23].

Juginovic et al. [24] also investigate the health impacts of exposure to air pollution in 43 European countries. In line with the previous study, the authors indicate a decrease of 42.4 per cent in pollution-related deaths from 1990 to 2019, in which approximately 90 per cent of the deaths are associated with $PM_{2.5}$. Furthermore, they estimate using a multiple regression model that for a 10% increase in $PM_{2.5}$ there is a 16.7% increase in the Years of Life Lost (YLL).

Finally, the recent study by Liu et al. [18] analyses the air pollution-mortality correlation for 372 cities, showing significant associations between total mortality and exposure to $PM_{2.5}$ and O_3. Specifically, a 10 $\mu g/m^3$ increase in $PM_{2.5}$ and O_3 are associated with 0.79% and 0.31% increases in total mortality, respectively.

With regard to long-term exposure to air pollution, Luo et al. [25] investigate the health consequences of exposure to fine PM in China. The authors estimate that a

10 $\mu g/m^3$ increase in $PM_{2.5}$ is associated with 15.1%, 11.9% and 21.0% increases in mortality from cardiovascular causes, stroke and lung cancer, respectively.

Again, the meta-analysis conducted by Chen and Hoek [26] shows that combined Hazard Risks (HR) for natural-cause mortality are 1.08 per 10 $\mu g/m^3$ increase in $PM_{2.5}$, and 1.04 per 10 $\mu g/m^3$ increase in PM_{10}.

Table 1 below provides a summary of the main literature studies investigating the correlation between air pollution-mortality/human health damage.

4 Economic Valuation Methods for the Health Effects of Environmental Pollution

The consequences of air pollution affect both the market costs associated with the bio-physical effects directly quantified in GDP and the non-market costs associated with the social costs associated with mortality and morbidity. Improved air quality through new green infrastructure reduces negative impacts on the health of the population, such as mortality and morbidity. Therefore, the evaluation of the economic benefits deriving from the reduction of air pollution from PM and ozone thanks to vegetation can be expressed as a function of the lower harmful effects on human health [41].

The economic evaluation of the health impacts of air pollution occurs through two different phases: (1) the identification and subsequent measurement of the health impacts, which consists first in establishing the average environmental concentration levels of a pollutant and then in placing relating these concentrations to health effects through Dose-Response Functions (DRFs). These are functions that correlate mortality and morbidity outcomes of susceptible population groups with ambient concentrations of a certain air pollutant; (2) estimating monetary values for associated mortality and premature morbidity.

The methods used to assess the health costs associated with environmental pollution can generally be divided into two categories:

i. methods that measure only direct loss of income, such as lost wages or cost of illness (COI);
ii. approaches that estimate individuals' Willingness To Pay (WTP) to avoid or reduce the risk of death or disease.

4.1 Methods Measuring Loss of Income

Methods that measure only direct income loss include:

a. the human capital approach to assess the effects of pollution, in terms of mortality;
b. the Cost Of Illness (COI) approach to account for the implications in terms of changes in morbidity.

The human capital approach (a), which places a value on a premature death, is based on the economic productivity of an individual and values life according to the net present value of an individual's productivity. If individuals are understood as units of human capital that produce goods and services for society, then the value of each unit of

Table 1. Literature review on the correlation between in-air pollution-mortality.

Author(s) and year	Mean/median exposure ($\mu g/m^3$)	Study period	Study location	Main Outcomes
$PM_{2.5}$				
Villeneuve [27]	9.5	1980–2005	Canada	HR (95% CI) per 10 $\mu g/m^3 = 0.97$ (0.80–1.18)
Pinault et al. [28]	5.9	2001–2011	Canada	HR (95% CI) per 10 $\mu g/m^3 = 1.17$ (0.98–1.40)
Turner et al. [29]	12.6	1982–2004	USA	HR (95% CI) per 10 $\mu g/m^3 = 1.09$ (1.03–1.16)
Pinault et al. [30]	7.1	2001–2012	Canada	HR (95% CI) per 10 $\mu g/m^3 = 1.16$ (1.07–1.25)
Yin et al. [31]	40.7	1990–2006	China	HR (95% CI) per 10 $\mu g/m^3 = 1.12$ (1.09–1.16)
Cakmak et al. [32]	6.5	1991–2011	Canada	HR (95% CI) per 10 $\mu g/m^3 = 1.29$ (1.06–1.59)
Juginovic et al. [24]		1990–2019	Europe (43)	For a 10% increase in PM2.5 there is a 16.7% increase in the Years of Life Lost (YLL)
Sui et al. [22]	66.18	2013–2018	China (Hefei)	10 $\mu g/m^3$ increase: increase of 0.53%, 0.93%, 0.90% in in non-accidental, cardiovascular and respiratory diseases
Sicard et al. [23]	-	2000–2017	Europe (28)	Decrease in the annual number of deaths by 4.85 per 10^6 inhabitants
Liu et al. [18]	-	1994–2020	19 Countries	10 $\mu g/m^3$ increase: 0.79% increase of total mortality

(*continued*)

Table 1. (*continued*)

Author(s) and year	Mean/median exposure ($\mu g/m^3$)	Study period	Study location	Main Outcomes
Luo et al. [25]	-	2016–2020	China	10 $\mu g/m^3$ increase (long-term exposure): 15.1%, 11.9% and 21.0% increase in mortality from cardiovascular causes, stroke and lung cancer
PM_{10}				
Bentayeb et al. [33]	25	1989–2013	France	HR (95% CI) per 10 $\mu g/m^3$ = 1.18 (1.06–1.32)
Fischer et al. [34]	29	2004–2011	Neth	HR (95% CI) per 10 $\mu g/m^3$ = 1.08 (1.07–1.09)
Chen et al. [35]	144	1999 - 2009	N. China	1.01 (1.01 -1.01)
Hansell et al. [36]	20.7	1971–2009	Eng.Wales	HR (95% CI) per 10 $\mu g/m^3$ = 1.24 (1.15–1.32)
Badaloni et al. [37]	36.6	2001–2010	Italy	HR (95% CI) per 10 $\mu g/m^3$ = 1.02 (1.01–1.03)
Kim et al. [38]	56	2002–2013	S. Korea	HR (95% CI) per 10 $\mu g/m^3$ = 1.05 (0.99–1.11)
O_3				
Bentayeb et al. [33]	101	1989–2013	France	HR (95% CI) per 10 $\mu g/m^3$ = 0.98 (0.90–1.06)
Turner et al. [29]	94.2	2002–2004	USA	HR (95% CI) per 10 $\mu g/m^3$ = 1.01 (1.01–1.01)
Cakmak et al. [32]	78.4	1984–2011	Canada	HR (95% CI) per 10 $\mu g/m^3$ = 1.01 (1.01–1.07)
Di et al. [39]	90	2000–2012	USA	HR (95% CI) per 10 $\mu g/m^3$ = 1.01 (1.01–1.02)

(*continued*)

Table 1. (*continued*)

Author(s) and year	Mean/median exposure (μg/m^3)	Study period	Study location	Main Outcomes
Weichenthal et al. [40]	76.6	2001	Canada	HR (95% CI) per 10 μg/m^3 = 1.03 (1.02–1.03)
Sicard et al. [23]	-	2000–2017	Europe (28)	Increase in the annual number of O_3-related premature deaths per 106 inhabitants
Liu et al. [18]	-	1994–2020	19 countries	10 μg/m^3 increase: 0.31% increase of total mortality

human capital corresponds to the present value of the future output that the individual could have generated had he or she not died prematurely [41].

According to the COI approach (b), the direct costs of morbidity include: medical expenses for treating the disease; lost wages during days off work and other days when activities are significantly restricted by the disease.

El-Fadel and Massoud [41] estimate for Lebanon the economic benefit due to reduced morbidity and mortality per 10 mg/m^3 reduction in PM_{10}. The economic benefit from reduced mortality is evaluated using the human capital approach and is in the range of 0.27 to 12.6 MUS$/year; while the benefit from reduced morbidity is evaluated using the COI approach and is in the range of 0.14 to 3.2 MUS$/year.

Panteli and Delipalla [42] analyse the economic cost of the health impact from air pollution using the COI in Greece. They estimate that illnesses attributable to air pollution resulted in a total economic cost of 1.27 billion euro in 2019, or 0.68% of GDP. Pascal et al. [43], using the COI approach, estimate for 22 European cities the annual economic benefits associated with a decrease of 5 μg/m^3 in both PM_{10} and O_3. In the case of PM_{10}, the average value of the annual benefit is EUR 7.194 thousand for hospitalisations due to respiratory problems and EUR 3.990 thousand for cardiovascular diseases. With regard to O_3, these economic benefits are worth EUR 206 and 1.256 thousand respectively. Again, Syuhada et al. [44] estimate that each year in Jakarta Province more than 5,000 hospitalisations can be attributed to air pollution, resulting in an annual COI of approximately USD 6.2 million.

4.2 Methods Measuring Loss of Income

As with methods measuring loss of income, WTP-based methods can be applied to assess both mortality effects and morbidity effects. If mortality effects are to be analysed, WTP consists of asking people directly how much they would be willing to pay for a marginal reduction in the risk of death. WTP is assessed through the Value of Statistical Life (VSL). Although there are ethical arguments against placing a value on human life, the

VSL is generally widely adopted to assess the health effects of particulate pollution [45]. Indeed, it expresses «the value of a small change in the risk associated with the dying of an unnamed member of a large group» [46]. The variation in VSL depends mainly on the context considered (sector, developed/developing country, socio-economic status, etc.) rather than on the method used [47]. Formally:

$$VSL = dap(\Delta\pi)/\ \Delta\pi \tag{1}$$

Where:
$\Delta\pi$ = considered variation in risk;
dap($\Delta\pi$) = willingness to pay for a $\Delta\pi$ change in risk.

The literature provides a wide range of empirical studies, commentaries and reviews that return VSL values. Just to name a few, the U.S. Department of Health and Human Services (HHS) [48] estimates a VSL of 9.3 million in 2014 USD. These values are based on a range of estimates from three Stated Preference (SP) studies from 2001–2013 and six hedonic wage studies from 2004–2013. The US Department of Transportation (DOT) [49] uses a similar central estimate of 9.6 in 2015 dollars. This estimate is derived from an average of nine studies on hedonic wages from 1997 to 2003. The US Environmental Protection Agency (EPA) [50] is the only one among the three US agencies that uses a meta-analysis estimating a value of 11.2 million in 2019 dollars for VSL [50, 51]. Masterman and Viscusi [52] recommended instead relying on meta-analysis of wage-risk studies that use data from the U.S. Census of Fatal Occupation Injuries (CFOI), estimating a VSL $9.6 million (2015 USD).

Significantly different from the value estimated by the three US agencies is the VSL provided by the Organisation for Economic Cooperation and Development (OECD), which is USD 3 million 2005. This value, based on meta-analysis, ranges between USD 1.5 and 4.5 million [53, 54]. The OECD estimate is also taken up by the World Bank and IHME [55], which use a VSL value of 3.8 million 2011 USD. More recently, Banzhaf [56] yields a central VSL of $8.0 m, with a 90% confidence interval of $2.4-$14.0 m, using data from seven different meta-analyses.

Keller et al. [47] value VSLs that vary significantly depending on the context (sector, developed/developed country, socio-economic status, etc.): the median value is $5.7 million in 2019; whereas the VSL is worth $6.8 million for the health sector, $8.7 million for the labour market and $5.3 million for the transport safety sector.

Robinson et al. [57] also point out the strong discrepancy that must exist between VSL in high-income countries and VSL in developing countries. In fact, estimates of the US VSL suggest that the average US resident is willing to pay sums close to USD 1,000 for a mortality risk change of 1 in 10,000, or about 1.6–1.7% of Gross National Income (GNI) per capita. In low-income countries, this amount would represent most or all of an individual's annual income. Thus, the individual WTP per unit of risk reduction is expected to decrease as income decreases, resulting in a lower VSL [57].

This is confirmed by some recent studies that provide VSLs for developing countries. In this regard, Huu et al. [58] employ a Vietnamese VSL between $647,050 and $981,200 (2011 US $, PPP) in their study. Cao et al. [45] estimate that VSL in China in 2019 ranges from CNY 3.79–6.36 million (USD 549,395–921,940), with an average value of CNY 4.76 million (USD 689,659).

Table 3 gives the main VSL values suggested by government agencies and industry studies.

Table 3. Comparison of VSLs.

Source	Country	VSL estimate
US DHHS [48] (2014 USD)	USA	$9.3 million
US DOT [49] (2015 USD)	USA	$9.6 million
US EPA [50] (2019 USD)	USA	$11.2 million
Masterman and Viscusi [52] (2015 USD)	USA	$9.6 million
Banzhaf [56]	USA	$8.0 million
OECD [53] (2005 USD)	OECD Countries	$3.0 million
World Bank and IHME [55] (2011 USD)	OECD Countries	$3.8 million
Keller et al. [47]	Mata-analysis of 120 studies conducted on both developing and developed countries	$5.7 million (median value) $6.8 million (health sector) $8.7 million (labour sector) $5.3 million (security and transport sector)
Huu et al. [58] (2011 $ US, PPP)	Vietnam	$ 647,050 - $ 981,200
Cao et al. [45]	China	$ 689,659

If morbidity effects are to be assessed, the WTP approach estimates how much people would be willing to pay to avoid the disease. This can be done by following two different methods: (i) the averting behaviour method, according to which the time and money spent by an individual to avoid exposure to air pollution – or to avoid a disease – is indicative of a minimum value he or she attaches to prevention; (ii) the contingent valuation method, which uses survey information to determine how much people are willing to pay to avoid a given symptom or disease.

The category of approaches that exclusively measure net income loss does not include intangible impacts on the well-being of individuals such as inconvenience, suffering, and loss of leisure time. In addition, such methods may underestimate the cost of the health of people who are not part of the labour force [41].

In contrast, WTP-based approaches are also able to capture intangible aspects. Therefore, according to some authors, WTP provides a more robust measure of effects on both morbidity and mortality and are therefore more widely used [58].

5 Discussion of the Results and Conclusions

Green Infrastructure (GI) can mitigate the negative effects of air pollution from particulate matter and ozone, with benefits for human health. But what is the economic value of these benefits? To answer this question, it is first necessary to measure the reduction in pollutant concentrations resulting from the creation of green infrastructure. This reduction in concentrations must then be related to health effects through dose-response functions. So, the effects are estimated in monetary terms.

Methods for assessing the health costs associated with environmental pollution can be grouped into two categories: (i) methods that measure only direct income losses, such as lost wages or the cost of illness; (ii) approaches that estimate individuals' Willingness To Pay (WTP) to avoid or reduce the risk of death or illness.

Focusing on the impact of mortality, WTP consists of asking the community how much they would be willing to pay for a marginal reduction in the risk of death: we arrive at the Value of Statistical Life (VSL). To give a clear indication of the economic cost of air pollution mortality for Italy, it is assumed that the number of deaths attributable to $PM_{2.5}$, PM_{10} and O_3 is 20,062, 15,112 and 3,490 respectively. Therefore, assuming a cost of living of 3.8 million Euro [55], the total economic loss is approximately 76 billion Euro for $PM_{2.5}$, 57 billion Euro for PM_{10} and 13 billion Euro for O_3.

Since the combined HRs for mortality for a 10 $\mu g/m^3$ increase in $PM_{2.5}$, PM_{10} and O_3 are 1.08, 1.04 and 1.03, respectively [59], it follows that for each variation (positive or negative) of 10 $\mu g/m^3$ of the pollutant there is an economic loss or benefit of about 6.1 billion euros for PM, 2.28 billion euros for PM10 and 0.39 billion euros for ozone. It can be concluded that investment in GI can have a significant impact on improving air quality and reducing mortality and morbidity, resulting in significant economic benefits for the community.

However, economic quantification is complicated by the delayed nature of the effects of pollution and the uncertainty of the data. The WTP methodology is limited by the lack of familiarity with the symptoms studied and the low frequency of some conditions in daily life, which leads respondents to give monetary values that are not always representative. Furthermore, relying mainly on the reduction in the risk of death from accidents does not take sufficient account of the specific nature of the risk of death from air pollution and the characteristics of the people potentially affected.

The estimates that can be obtained by applying WTP are more complete because they also take psychological effects into account. At the same time, it has limitations that reduce its applicability. According to McCubbin et al., WTP would vary not only according to the number of days of illness and the type of illness, but also according to whether willingness to pay is assessed for each symptom or for the simultaneous occurrence of several illnesses together.

At first glance, the COI would seem to be a more reliable estimation tool than the WTP, as it provides greater certainty about the expenditure components to be included in the cost-of-illness approach. However, even in this case there are some methodological limitations, as the COI varies according to the characteristics of the public health system of the reference country. On the other hand, when referring to private expenditure on the purchase of medicines, the level of per capita income plays a key role.

For both methods, there is also the question of the definition of individual symptoms. Although there is an internationally agreed codification, the process of assigning symptoms to the respiratory and cardiac systems is complex and ambiguous.

In a research perspective, we intend to characterise a model capable of correlating the amount of particulate matter and ozone absorbed annually by green infrastructures [60] with the impact on human health, expressed both in terms of lower health care costs due to the reduction in illnesses, and in terms of greater economic benefits due to the reduced number of deaths. This economic forecast will be able to raise awareness of the importance of ecosystem services in urban areas.

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Life Cycle Costing and BIM: An Integrated Approach for a Sustainable Construction Sector

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Abstract. The construction sector, responsible for 30% of global greenhouse gas emissions, plays a crucial role in land-use planning and quality of life. The integration of Life Cycle Costing (LCC) with Building Information Modeling (BIM) emerges as a promising approach to guide sustainable decisions in the construction lifecycle. Adopting a holistic approach, LCC considers the entire life cycle of the civil construction, providing a clear view of costs over time for informed and sustainable decisions. Despite the increasing use of LCC by public authorities and productive sectors, its implementation encounters challenges related to the complex management of the necessary data. The use of BIM facilitates the implementation of LCC by simplifying the collection, management and analysis of data in a unified digital environment. The automation of life-cycle costing processes reduces the complexity and time required for analysis, making it more accessible and convenient. The aim of the study is to provide an extensive analysis of LCC, outlining its limitations and examining how integration with BIM can overcome them. The synergy between BIM and LCC is not just a technological adaptation, but a key strategy to move the construction industry towards a sustainable approach, improving operational efficiency and reducing the environmental impact of construction activities.

Keywords: Life Cycle Costing · Building Information Modeling · Sustainability

1 Introduction

The construction sector plays a fundamental role in defining the planning of our territory and influences the quality of daily life. Buildings are, in fact, an important source of greenhouse gas emissions, consumption of natural resources and waste generation. According to the United Nations Organization, the construction sector is responsible for about 30% of global greenhouse gas emissions. [1, 2]. The most impactful phases of a civil construction life cycle are the extraction and production of materials, which, for residential buildings, account for about 90% of the total environmental impact and 60% of construction costs [3].

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In this context, the integration of Life Cycle Costing (LCC) with Building Information Modeling (BIM) emerges as a promising approach to guide decisions toward sustainability across the full life cycle of a building.

Indeed, the LCC approach, as opposed to traditional cost assessment approaches, takes a holistic approach, considering the entire life cycle of the building, including construction, maintenance, energy and decommissioning costs [4, 5]. This provides a clearer and more accurate view of costs over time, enabling informed and sustainable decisions even in the long term. LCC makes it possible to optimize the financial resources required during the entire existence of the work and to reduce the impact that construction has on the environment. This approach is currently being adopted by a growing number of public authorities throughout the EU and in many productive sectors. In the context of sustainable public procurement, it has acquired a key role, guiding governments toward the choice of "green," socially and economically sustainable goods and services [6].

However, LCC implementation often faces limitations associated with the complex management and accessibility of the vast amount of necessary life-cycle cost data, which must be collected from a variety of sources [7, 8].

In this sense, the use of BIM can facilitate the application of LCC from several perspectives. Indeed, BIM enables the collection and management of a work's data within a unified digital environment. This not only simplifies data collection and sharing, but also improves data quality. In addition, BIM can automate some life-cycle costing processes, reducing the complexity and time required to perform the analysis. Such automatization makes the analysis itself more accessible and convenient [9].

In light of the above, the objective of the paper is to provide an in-depth analysis of the application of Life Cycle Cost (LCC), with particular emphasis on outlining the inherent limitations of this approach. The intent is also to examine how the integration of LCC with Building Information Modeling (BIM) can overcome these limitations and address the challenges associated with its practical implementation. The joint adoption of these methodologies can, in fact, optimize the process of collecting, managing and analyzing life cycle cost data. It is also shown how the synergy between BIM and LCC is not just a technological adaptation, but rather a key strategy to move the construction industry toward a more sustainable approach that not only improves operational efficiency, but can significantly contribute to reducing the environmental impact of construction activities, therefore promoting sustainable progress in the industry.

The study is structured as follows: Sect. 2 outlines the concept of Life Cycle Costing (LCC) analysis, explaining its methodological framework and main types; Sect. 3 delves into the topic of Building Information Modeling (BIM), elaborating on the innovations introduced in the construction field and highlighting its relative advantages; Sect. 4 focuses on the analysis of integration between BIM and LCC, examining its potential and how it can be integrated operationally; and finally, the conclusions deal with the limitations encountered in BIM-LCC integration and present possible research perspectives in this direction.

2 Life Cycle Costing Approach

Life Cycle Costing (LCC) is an economic evaluation methodology that allows the costs of a product or service to be compared throughout its life cycle, taking into account all relevant economic factors, both initial and future [10].

There is no international standard that uniquely defines the approach; however, there are several standards and guidelines that provide guidance on how to apply it [11, 12]. In Italy, for example, the UNI 11469:2018 standard "LCC - Life Cycle Costing - Guide to Life Cycle Cost Assessment" provides guidance for the application of LCC in the construction sector.

Unlike usual financial evaluation techniques, LCC adopts a holistic perspective, contemplating both investment and operational costs associated with each stage of the product life cycle, following a cradle-to-grave view [13, 14]. These costs include the costs of planning, design, construction, operation, and decommissioning [15].

This approach allows for a more comprehensive and realistic assessment of the overall costs of a product or service, including environmental sustainability.

The LCC is a decision support tool to be used both for the evaluation of a single product and for the analysis of an entire component system, as well as for ex-novo construction and retrofit projects.

The objectives of the approach are multiple such as comparing alternative technical solutions, identifying a hierarchy of alternative designs, as well as evaluating the budget of a specific selected project over a given life period [16].

Based on the findings of the literature, four main types of Life Cycle Cost (LCC) can be distinguished. The choice of the type of LCC to be adopted is conditioned by the specific objectives of the analysis and the available resources. We distinguish:

- *Financial Life Cycle Cost* (fLCC), which considers the internal costs associated with a specific product and incurred by a specific actor [17]. This type of LCC is the most simple and fast to apply, as it focuses on the costs directly attributable to the product or service under consideration. However, it provides a limited view of overall costs, as it does not take into account environmental and social costs.
- *Environmental Life Cycle Cost* (eLCC), which assesses all costs incurred by actors related to a specific functional unit and includes both internal environmental costs, incurred directly by the company, and external environmental costs, incurred by third parties [18].
- *Full-environmental Life Cycle Cost* (feLCC), which also takes into account monetized environmental externalities. This type of LCC is the most complete, as it also includes environmental externalities, which are the environmental costs that are not borne directly by the company producing or distributing the product or service, but by third parties.
- *Social Life Cycle Cost* (sLCC), which, compared to the previous types, adds social costs incurred by both the company and third parties, such as employee training costs or the costs of illnesses caused by chemicals in a product.

The LCC methodological framework typically follows four main steps [19, 20]: 1) Briefing; 2) Problem analysis; 3) Study and calculation; 4) Validation and interpretation of results.

In step (1) of *briefing*, the main focus is on defining the objectives of the analysis, the scope and the time horizon of the evaluation. Defining the objectives of the analysis is of twofold importance: first, it facilitates the identification of relevant costs to be included in the scope of the analysis; second, it allows the scope of the evaluation to be accurately delimited. The definition of the time horizon is equally crucial, as it affects the life-cycle cost estimation of the good. In the context of sustainable development, it is strongly argued that life-cycle cost analysis should extend to the entire life cycle of a product or service [21].

In step (2) of *problem analysis*, the cost items that need to be estimated are identified:

1. Construction costs or investment costs (C_i), which include the expenses required to build the asset, such as site acquisition charges, design fees, financial charges and tax deductions.
2. Maintenance costs (C_m), which are all costs incurred to ensure that the specific functional performance of the asset is maintained. This includes renovations, periodic inspections, routine and extraordinary maintenance.
3. Operation costs (C_o), which are the costs necessary to ensure the proper functioning of the facility and are divided into ordinary and extraordinary. The former are all costs for normal custody and routine repairs, annual maintenance contracts, and salaries of maintenance service personnel. Extraordinary maintenance costs cover: replacement of components of a plant and/or structure due to end of life; renovation due to functional alteration or upgrading, etc.
4. End of life costs (C_{el}), which cover both disposal and demolition costs and income generated at the end of the asset's useful life. These include residual value (V_r), which represents the monetary value assigned to the asset at the end of the LCC analysis period, and the terminal or scrap value of a component or asset at the time of its replacement.

Step (3) of *study and calculation* begins with the collection of the necessary data, followed by the application of computational models to estimate the previously identified cost items. The source of data can come from a variety of sources, such as (i) information provided by the manufacturer or supplier of the item; (ii) data available in technical or trade publications; and (iii) information obtained through surveys or interviews. Data collection and analysis constitute a major and complex activity, requiring specialized skills.

Initially, costs and benefits are estimated, generally expressed through financial savings. Next, economic performance indicators are calculated, including Net Present Value, Net Present Cost, Net Savings, Simple/Discounted Pay Back Period etc.

Generally, the results of Life Cycle Costing analysis are expressed in terms of Global Cost (CG), which is the sum of the present value of all life cycle costs, including residual values. CG is defined as:

$$CG = C_c + \sum_{t=1}^{n} \frac{C_m + C_0 + C_{el} - V_r}{(1 + r)^t}$$

where:

C_c = investment costs;
C_m = maintenance costs;

C_o = operation costs;
C_{el} = end of life costs;
V_r = residual value;
t = year in which the cost is incurred;
n = number of years of the analysis;
r = discount rate.

The discount rate r makes monetary terms that occur at different time instants financially comparable and reflects the time value of money [22, 23].

Finally, step (4) of *validation and interpretation of the results* is aimed at verifying the defined assumptions, making a judgment on the economic performance of the investment, and analyzing at which stages of the life cycle the higher costs are incurred. The results obtained are to be validated through various methods, such as comparison with historical data, sensitivity analysis, and the use of statistical techniques. The results of the entire process will be able to guide strategic choices and help improve the efficiency and effectiveness of investments.

3 A Revolution in the Construction Industry: Building Information Modeling (BIM)

Building Information Modeling (BIM) is defined by the National Institute of Building Sciences (NIBS) as the "digital representation of the physical and functional characteristics of an object." BIM goes beyond simple three-dimensional representation or the use of software; it constitutes an advanced technology aimed at generating a shared, multidisciplinary information model. Such a model incorporates information relevant to each stage of the design process, from architectural to executive and management aspects. While previous workflows were based on multiple files and disconnected processes, with BIM the approach becomes more dynamic and facilitates the sharing of knowledge and data, the exchange of information, and the participation of all parties involved in the various phases by reducing the error rate and the number of changes [24].

The virtual model that is generated can contain all the information about the entire life cycle of the work, from design to construction to its demolition and decommissioning. The BIM model can also be used to represent nonphysical building information, such as energy, environmental, and structural performance information. This enables architects and engineers to design more efficient and sustainable buildings [25, 26].

The BIM model is, therefore, a set of intelligent parametric objects that represent the physical and functional elements of a building. These objects can be linked with each other and with associated information, such as technical specifications, costs, construction time, etc. In essence, it is not just about 3D modeling; the Italian UNI 11337-6 standard identifies seven dimensions of Building Information Modeling that refer to the different levels of information that can be found in a BIM model.

Notably, three-dimensional (3D) geometric modeling represents only the initial phase of Building Information Modeling (BIM) and is the basis for creating a detailed model of the building.

The fourth dimension (4D) integrates the geometric information of the 3D model with the time variable, creating a useful model for simulating the construction process, identifying potential conflicts, and optimizing planning.

The fifth dimension (5D) links the geometric information in the 3D model to costs, creating a model that can be used to estimate construction costs, monitor costs during the construction phase, and identify possible savings opportunities.

The sixth dimension (6D) allows the BIM model to be used for operational management of the building, including aspects such as maintenance and repair.

Finally, the seventh dimension (7D) allows the BIM model to be used to assess the building's energy and environmental performance. This allows technical solutions to be adopted to reduce energy consumption, thus contributing to the sustainability of the project and meeting economic and social requirements.

Charef [27] stressed the importance of BIM models in the context of the Circular Economy and proposed assigning an eighth dimension (8D) to activities related to the sustainable management of the structure toward the end of its life cycle.

In Italy, the adoption of (BIM) was formally introduced in 2017 through Ministerial Decree 560/2017. This decree made the use of BIM mandatory for public works with a value greater than 100 million euros. In addition, the decree outlined a phase of gradual implementation, stipulating that the obligation to adopt BIM will be extended to all public works with a value greater than €1 million starting in 2025.

In light of the above, the main advantages of BIM over conventional design and construction methods can be identified.

- Improved communication and collaboration: BIM promotes more effective communication and optimal collaboration among the various stakeholders involved in the process. The ability for all stakeholders to access the same information in real time promotes data sharing and synergistic cooperation [20].
- Data accuracy and reliability: BIM enables the capture and management of information with greater accuracy and reliability than traditional methods. This helps ensure the consistency and integrity of data used in the design and construction process.
- Optimized design and construction decisions: through simulations and virtual analysis, BIM provides detailed information that supports decision making during the design and construction phases. This capability enables the formulation of more informed and strategic decisions [28].
- Reduced construction costs and time: BIM helps identify potential problems and opportunities for improvement before the actual start of construction, enabling more efficient planning and a reduction in both overall costs and construction time [29, 30].
- Increased sustainability of the work: through the optimization of energy efficiency and efficient use of resources, BIM supports the overall improvement of the sustainability of construction works. This approach helps reduce environmental impact and promote more environmentally sustainable construction practices.

4 The Integration of BIM and LCC: A Promising Approach for Construction Sustainability

The integration of BIM and LCC represents a significant step toward the optimal management of construction projects. The combination of detailed information offered by BIM and the comprehensive cost analysis provided by LCC promises to radically transform the construction industry, enabling projects that are more sustainable, efficient, and cost-effective in the long term.

Synergistic integration between BIM and LCC has a number of notable benefits, including the following:

- Improved accuracy of cost estimates. The use of the information provided by the BIM model enables more accurate estimation of building lifetime costs, overcoming the inherent limitations of traditional methods. This approach reduces financial risks and optimizes project planning. The visual tools and detailed asset and material information provided by BIM help increase the accuracy and consistency of LCC results [30]. In addition, the BIM model can quickly update LCC results in response to design changes [20].
- Increased efficiency of decision-making processes. Integration between BIM and LCC empowers designers and decision-makers to make more informed decisions about building design and construction. This synergy promotes more efficient, sustainable, and cost-effective projects.
- Improved sustainability. The combination of BIM and LCC helps mitigate the environmental impact of buildings by enabling designers to select more sustainable materials and to conceive buildings with lower energy consumption. BIM facilitates detailed cataloging and tracking of materials, proving crucial to the Circular Economy by emphasizing the reuse and recycling of materials [31]
- Cost-effectiveness in the long run. Integration between BIM and LCC helps contain costs related to building maintenance and decommissioning over time, generating long-term economic benefits.

The operational integration of an LCC analysis to BIM can be implemented through several ways. One common approach is to use a dedicated BIM plugin for LCC analysis. Such plugins are software tools that allow life-cycle cost analysis to be integrated into BIM models by importing LCC data from a variety of sources, including Excel files, databases and material suppliers, and calculating the total costs of a building over its life cycle.

Some of the most popular plugins are: (a) Navisworks Quantification, part of the Autodesk suite, which offers quantification tools to extract cost information from the BIM model and can be integrated with LCC software for cost analysis This can be integrated with LCC software for cost analysis; (b) Solibri Model Checker known for quality control of the BIM model, but also can be used for cost analysis by integrating cost data associated with BIM objects; (c) CostX, BIM quantification software, which allows import of LCC data from a variety of sources, such as databases, publications, and material suppliers.

An alternative is to use LCC analysis software that supports BIM data, allowing direct import of data from the BIM model. The software then processes the total costs of the building over its life cycle using the information provided by the BIM model. Examples of software include (a) One Click LCA, developed by One Click LCA, which supports BIM data from Revit, ArchiCAD, Tekla, and others and, through the One Click LCA LCC tool, allows estimating costs for all phases of the life cycle; (b) Trimble Quantm, which offers cost analysis capabilities integrated with BIM models, allowing costs to be estimated throughout the project life cycle;

Finally, an LCC analysis can be manually merged with the BIM model. This approach requires manual collection and input of total building cost data into the BIM model.

Figure 1 illustrates the integration process between Life Cycle Cost (LCC) and Building Information Modeling (BIM).

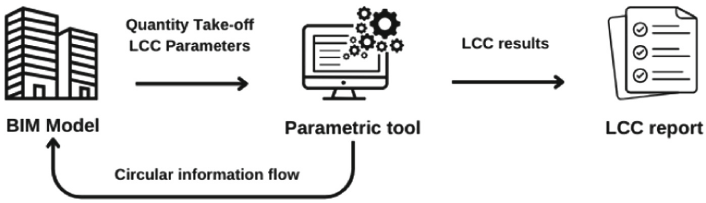

Fig. 1. Integrated approach BIM-LCC.

5 Conclusions

The activities of the construction sector, traditionally aimed at creating infrastructure and buildings, substantially affect the surrounding environment and directly affect the quality of life of communities. The construction sector is one of the world's most important economic sectors and is responsible for about 30% of global greenhouse gas emissions and the use of about 40% of natural resources [32].

Awareness of the importance of sustainability is driving the sector to adopt increasingly environmentally friendly practices and integrate innovative technologies to achieve long-term environmental goals. The European Union, for example, has set a goal of making all new or renovated buildings nearly zero energy by 2050 [33].

In this context, the work promotes the integration of Life Cycle Costing (LCC) with Building Information Modeling (BIM) as a promising approach for guiding decisions toward environmental sustainability over the full life cycle of a work. The integration of LCC and BIM can provide a comprehensive view of the cost and environmental impact of a work, from the earliest stages of design. This can help identify opportunities for sustainability improvements, such as using more sustainable materials and technologies, or designing buildings that are more energy efficient.

Despite the obvious advantages, highlighted in Sect. 3, there are still significant challenges to be faced in integrating BIM and LCC. One of the key limitations concerns data availability. Both methodologies require a vast set of information, whether related to the structural characteristics of buildings or infrastructure or the costs associated with materials and technologies. The retrieval and consistent integration of such data can be complex. A second limitation is the inherent complexity of the technology itself. Integration between BIM and LCC requires specialized skills, making its large-scale implementation and adoption arduous.

In light of the above, research perspectives could focus on the development of methodologies and frameworks aimed at efficient integration of BIM information with life-cycle cost data. A significant approach could be to standardize practices and establish protocols to ensure consistency and ease of implementation of such integration. The application of this methodology to a specific case study proves relevant to evaluate its effectiveness in real-world settings.

Another area of research interest could be the integration of Circular Economy principles into the BIM-LCC context. Exploring how these principles can be effectively incorporated into the integration methodology could provide new insights for sustainable life cycle management of construction works.

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Ethical Public-Private Partnerships: A Forward-Thinking Approach to Enhancing Public Assets

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Abstract. Since late 1990s, Italy's public administration has grappled with economic constraints, prompting the exploration of Public Private Partnerships (PPPs) as a solution to address infrastructure needs. However, the assessment of PPPs often neglects ethical considerations, raising questions about the social relevance and impact of such projects. This paper seeks to address this gap by developing a method for evaluating the social impact of PPP projects. By integrating ethical analysis with traditional investment evaluations such as Discounted Cash Flow (DCF) and Social Return On Investment (SROI), this approach offers a comprehensive understanding of different projects. Through this holistic approach, decision-makers can not only assess the financial viability but also ensure that the ethical implications of PPP initiatives are thoroughly examined. The proposed model will undergo testing in a future case study application. By examining the economic and social impacts of a student housing construction in the Santa Marta area, Venice, this framework will provide decision-makers with a well-rounded perspective. This will enable decision-makers to make informed decisions that prioritise both financial sustainability and ethical responsibility in PPP project implementation. Moreover, the model could potentially be adapted for use in other settings beyond university housing construction, offering a versatile framework for several contexts.

Keywords: Public private partnership · Ethic · Social return on investment · Student housing · Urban regeneration

1 Introduction

In the realm of urban improvement initiatives, it is crucial to define potential social benefits beforehand to align with the ethical objectives inherent in partnership process. Integrating an ethical dimension into the sturdy framework of Public-Private Partnership (PPP) offers a means for effectively intervening in enhancing Italy's public heritage. Expanding on these foundations, this paper aims to develop a replicable method-ology for evaluating social relevance during the feasibility phase of an urban regeneration project,

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with a specific focus on an illustrative case study. To attain this objective, traditional analyses commonly employed in assessing PPP investments, such as Discounted Cash Flow (DCF), were enriched by the incorporation of impact analyses.

These analyses are tailored to assess the non-financial returns on investments, particularly their social value, using, among others, the Social Return On Investment (SROI) framework. This comprehensive approach seeks not only to gauge the financial viability of enhancement projects but also to highlight their broader ethical and social implications. By integrating these diverse evaluation methods, synergy is fostered between financial and non-financial aspects, providing a holistic perspective on the investment. Through this analysis, both the private and public sectors can gain deeper insights into and address the ethical dimensions inherent in the investment.

The paper introduces fundamental concepts crucial for interpreting the methodology detailed in the following sections. This includes defining Sustainable and Responsible Investments and introducing the concept of Ethical PPP. It then proposes an economic-financial analysis framework for a student housing investment, linked to urban regeneration and social aspects of ethical finance.

The case study will focus on the urban renewal of Ca' Foscari University's Santa Marta area in Venice, specifically the construction of Campus Santa Marta student residence. This project serves as a bridge between PPP and Social Housing, facilitating an innovative approach to addressing housing needs while leveraging private investment. The evaluation methodology integrates DCF and SROI, providing a comprehensive assessment that surpasses traditional monetary metrics. This integrated approach allows for a more nuanced understanding of the project's value and potential benefits.

This research aims to provide a framework for future endeavours in enhancing public assets. The paper not only seek to enrich the understanding of ethical considerations in investment but also aims to guide and inform decision-makers in promoting projects that prioritise social sustainability within the framework PPP.

2 Public Private Partnership in the Framework of Sustainable and Responsible Investments

In recent times, the financial sector has shown increasing interest in investments with positive environmental and social impacts. Challenges such as environmental issues, climate change, education, security, and social housing are extending beyond the capacity of traditional public investments and welfare initiatives. Social Impact Investing (SII) has emerged as a thriving global market, involving banks, investment funds, social enterprises, and both public and private sectors. This trend often fosters collaborative efforts between private investors and the public sector, resulting in various forms of partnerships aimed at achieving tangible social impact. Within this landscape, Sustainable finance has gained prominence, prioritising capital deployment to address human needs and broader societal requirements beyond profit-seeking. Sustainable and Responsible Investment (SRI) serves as a framework for integrating social, environmental, and governance objectives into traditional investment strategies, ensuring that financial decisions align with ethical and sustainability principles.

The evolving mind-set of investors is evident as they move away from solely profit-driven financial instruments towards those that also uphold principles such as worker rights, environmental conservation, and human rights [1].

SRI strategies incorporate sustainability criteria, including environmental, social, and governance (ESG) aspects, enabling investors to align financial pursuits with broader societal and environmental goals. SRI strategies in Italy include:

1. **Thematic investment and ESG Integration**: Asset managers systematically incorporate ESG risks and opportunities into traditional financial analysis, focusing on areas like climate change, energy efficiency, and health.
2. **Engagement and voting**: Long-term dialogue on sustainability issues and exercising voting rights to positively influence issuer's behaviour and transparency.
3. **Impact Investing**: Investments in companies or funds aiming for measurable environmental and social impact while providing financial returns.
4. **Exclusions**: Explicitly excluding certain sectors from investment based on principles and values such as arms, pornography, tobacco, and fossil fuels.
5. **International norms based screening**: Selecting investments compliant with international norms and standards, such as those set by OECD, UN and its agencies.
6. **Best in class**: Prioritising issuers in a portfolio based on environmental, social, and governance criteria, favouring top performers within a category or asset class.

Impact Investments merge financial returns with positive social and environmental effects, stimulating innovation in welfare policies through social innovation tools. PPPs leverage diverse stakeholders' strengths, enabling the public sector to optimise resources despite funding constraints. This alignment fosters innovation and effectively addresses societal needs such as healthcare, infrastructures, and education development. The private sector benefits by diversifying its investment portfolio through active participation in PPPs. By prioritising innovative models focusing on social impact over profit-driven motives, private entities contribute to positive societal outcomes. This commitment to prioritising social impact underscores a commitment to responsible corporate citizenship, positioning the private sector as a catalyst for addressing urgent social challenges and driving positive societal outcomes [2].

PPPs play a crucial role in impacting the social innovation process, aiming to generate added value while shaping policies for social innovation. PPPs serve as an optimal structure for executing impact investing models, tackling financial disparities within the public domain through private investor involvement in initiatives targeting social needs [3]. The core challenge lies in encouraging PPP actors to move beyond financial gains and prioritise ethical considerations, hereby ensuring that partnership success aligns with moral values and societal well-being. By emphasising ethical goals alongside economic achievements, PPPs can contribute to positive and sustainable outcomes for both collaborators and the communities they serve. The public sector's emphasis on community welfare often contrasts with the private sector's focus on pursuing measurable outcomes, shaping the legal framework of PPPs. This divergence encompasses both "hard" constraints related to primary interests and "soft" constraints tied to governance and social aspects. Neglecting these soft constraints poses a risk of compromising project ethics, emphasising the necessity for explicit ethical principles in PPP contract implementation.

Socially, PPPs distinguish themselves from conventional business transactions by prioritising "horizontal values" such as reducing unemployment, fostering balanced regional development, and ecological preservation. These values underscore the ethical nature of PPP partnerships. PPPs offer valuable tools for resource management, planning, and policy coordination. Incorporating ethics from the outset can significantly enhance their success rates, with political legitimisation being crucial for recognising PPPs as innovative solutions for public interest projects [4].

While economic objectives remain significant, social responsibility in PPPs extends to cost reduction through technology, improving project quality, and supporting local businesses. Environmental considerations require efforts to mitigate negative impacts and contribute to global improvement. From an economic standpoint, ethics should transcend mere "value for money" assessments in PPP projects. Instead, emphasis should be placed on ensuring the integrity of the entire process, recognizing PPPs as an evolution of traditional procurement methods. This shift in perspective acknowledges the importance of ethical considerations in all stages of PPP development and implementation.

3 Understanding SROI: Assessing Social Returns on Investment Within PPPs

Historically, financial valuation has focused on monetary and investment aspects, often neglecting wider political, social, and environmental implications in fund allocation. Recently, it has been acknowledged that financial indicators falter when non-financial or extra-economic factors come into play. This challenge has spurred efforts to develop methodologies aiming to comprehensively integrate environmental and social impacts into investment decisions. Identifying the complexity of these influences, there is a concerted effort to move beyond traditional financial metrics and ensure a holistic assessment of investments across political, social, and environmental dimensions. Measuring social impact remains complex due to different factors as:

- **Attribution Challenge:** Identifying the participants/factors involved in the social scope of a project is inherently difficult, making it hard to attribute specific outcomes to particular elements;
- **Measurement of "Fluffy" Variables:** Assessing intangible aspects such as independence, self-esteem, or well-being involves grappling with the challenge of quantifying and measuring these subjective and often elusive variables;
- **Different Social Interventions:** Developing a standardised model for social projects is daunting due to the wide range of contexts in which these interventions occur, hindering the establishment of a one-size-fits-all approach;
- **Economic Aspects in Social Projects:** Economic principles often fail to capture the complexities in social projects, raising concerns about their applicability, as social initiatives involve dimensions beyond traditional economic considerations.

To tackle these challenges, the Roberts Enterprise Development Fund (REDF), a U.S. foundation specialising in social financing, pioneered a methodology in the late nineties known as Social Return on Investment (SROI). SROI assesses the social impacts of investments. It evaluates the "social value" of activities pursued by public institutions, foundations, or other social investors, and gauges the anticipated overall impact of specific projects or policies on the broader community [5].

Based on positivism, evaluation models like SROI aim to quantify the link between input and output using straightforward if-then logic [6]. SROI focuses on quantifying the social benefits of an investment, expressed as a coefficient for evaluation and comparison across alternatives. This coefficient represents the ratio of social value generated by an investment relative to its cost, allowing stakeholders to assess the efficiency and effectiveness of different investment options. This assessment entails evaluating social, environmental, and economic outcomes, all quantified in monetary terms, enabling the computation of a benefits-to-costs ratio. This structured framework helps assess the broader impacts of investments, revealing their social value beyond traditional financial metrics.

SROI represents a modern application of established evaluation techniques in projects, plans, and programs. Drawing from principles in social accounting and Cost-Benefit Analysis (CBA), SROI offers a more holistic approach by considering diverse impacts that social programs may bring about [5, 7]. SROI has also been applied to DCF [8], integrating discounted cash flows associated with benefits and costs over a specified period [9] or through the entire lifecycle [10].

Integrating SROI with social accounting and CBA/DCF yields a modern approach to evaluating project impact. This hybrid method combines economic principles with social and environmental factors, providing a more inclusive perspective surpassing traditional financial metrics.

Certain social value measurements can be quantified financially. For example, a program reducing unemployment not only cuts spending on social safety nets but also boosts future tax income. Yet, quantifying impacts like enhancing well-being poses challenges. In such cases, we adjust the SROI coefficient using data from quantitative and qualitative social science methods.

SROI analysis unfolds in two phases: evaluative, post-investment, and predictive, with the latter aiming to forecast social value. Though challenging, predictive analysis establishes benchmarks from project inception, offering comprehensive insights into social investments, both retrospectively and prospectively.

For SROI analysis to be effective, it requires an output that is as objective as possible and, more importantly, can be compared with other projects. This output is called the Impact Map and is derived by completing six steps (Fig. 1):

The SROI analysis faces challenges, particularly in measurement. Issues include [11] its silence on interpersonal comparisons, a bias towards outcomes of the wealthy, narrow views on stakeholders, susceptibility to biases in ratio calculation, and outdated or incomplete valuation theory and methodology. Economic evaluations like CBA also have shortcomings [12], failing to address intra- and intergenerational equity despite applying distributional weights and a social discount rate. Nevertheless, they prioritise efficiency over equity.

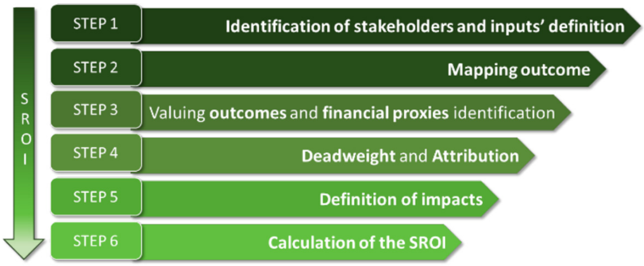

Fig. 1. Social return on Investment: six steps of the approach

4 Student Housing Investments in Venice: A Case Study

The student housing sector is experiencing a notable resurgence, driven by increasing demand from both international and domestic students, which is rapidly reshaping rental patterns. This dynamic landscape highlights the sector's growth potential and promising future. In Italy, Purpose-Built Student Accommodation (PBSA) emerges as a promising asset class, offering substantial investment opportunities and geographic diversification prospects. Currently, student accommodation supply in Italy significantly lags behind, with only a 3.8% provision rate, as reported by [13]. This contrasts with double-digit rates in more mature European markets, presenting an attractive investment opportunity to address the growing demand for student housing.

This analysis delves into the student housing market in Venice, focusing on the Santa Marta area. Despite its proximity to major transportation hubs, Santa Marta is considered semi-isolated. It hosts several university campuses of IUAV and Ca' Foscari. The project aims not only to establish a university campus but also to transform the area into a new hub for Venice, revitalising the neighbourhood and enhancing its connectivity and amenities. The Santa Marta area boasts significant transportation networks and residential fabric. To identify the potential catchment area for the university residence hall service, Ca' Foscari University conducted surveys on student housing demand and supply. The research revealed a potential demand for future student housing of around 9,200 students, excluding potential tourist occupancy. To address this demand, the Regional Company for the Right to University Studies (ESU) covers approximately 13% of the potential demand, leaving a surplus that could benefit from the new housing at the Santa Marta Campus.

The campus will provide a total of 650 beds, distributed among different categories: 82 beds for the ESU, 250 beds for Social Housing, and 318 places for the free market. Covering an area of 20,000 square meters (see Fig. 2), the complex includes communal areas and fully furnished single or double rooms equipped with *ensuite* bathrooms. Notably, the residence incorporates renewable energy systems to promote efficient energy consumption, including solar panels and photovoltaic systems.

With a capacity of 412 rooms, the facility effectively doubles the availability of university student accommodation in the city, addressing the current gap in affordable housing. Situated amidst historic buildings, the project exemplifies urban redevelopment, repurposing early twentieth-century structures previously underutilised.

Owned by Ca' Foscari University and leased to the Erasmo Real Estate Fund for 75 years, the project aims to optimise the area for student accommodation. The project received funding from different sources, including a contribution from the Ministry of Education, University and Research (MIUR).

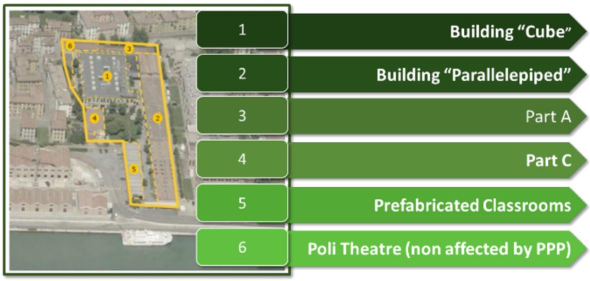

Fig. 2. Santa Marta: the case study

5 Integrating the Economic Analysis with Environmental and Social Issues: A Framework for a Future Application

The aim of this work is to introduce a methodological framework that will be quantified in following stages. The objective is to identify economic indicators such as Net Present Value (NPV) and Internal Rate of Return (IRR) through DCF, as well as to evaluate social and environmental impacts through SROI. Consequently, the goal is to establish a matrix that will be further developed in the future, leveraging information obtained from the tender process. Regarding Step 1 (Fig. 3), which entails economic and financial analysis using the DCF, we will take into account investment costs for the renovation of existing buildings and new construction. Additionally, operating costs and fees associated with the facility's management (Camplus) will be factored in.

$$NPV = \sum_{t=0}^{n} \frac{(R_t - C_t)}{(1+r)^t} \tag{1}$$

In that formula, R stands for revenues, C for cost (investment costs and running costs), n is the time horizon, and r is the discount rate.

Moving on Step 2, we will analyse energy data to understand the savings achieved in heating, cooling, and electricity consumption. This analysis will also shed light on reductions in energy consumption and CO_2 emissions. While the first two phases focus on investor and building indicators, the third step of the model involves creating an impact map to assess the relationship between the investment and the resulting social value. During the initial stage of Step 3, stakeholders affected by the project were identified, including individuals and organisations. Five key groups were identified in this case: students, Venetian universities, the Erasmus Fund, residents, and public transport authorities.

The core of SROI analysis is pinpointing changes relevant to each stakeholder group, as these changes suggest investments made in the project, whether consciously or unintentionally. Ensuring accuracy and relevance in delineating these changes is crucial for effectively quantifying the inputs. It is important to underscore that only actions resulting in a tangible (estimated) reduction in stakeholder resources should be considered when monetising inputs.

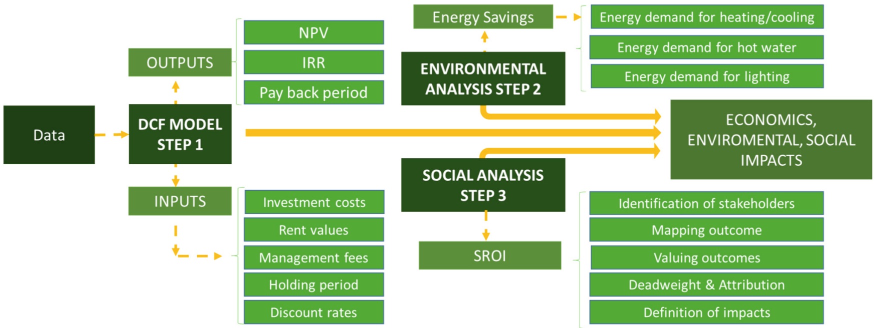

Fig. 3. The three steps methodology

Monetising inputs associated with direct stakeholders is relatively straightforward and is accomplished through the DCF method. However, inputs linked to indirect stakeholders pose greater challenges, requiring a subjective component from the valuer. For instance, property owners in the Santa Marta area might experience a decline in student rental demand in the years following the establishment of the facility, or they may find employment opportunities within the facility. Service establishments in the vicinity (such as supermarkets, shops, etc.) will likely experience an induced economic effect stemming from the presence of students. Additionally, students could feel safer, more independent and socially connected in the new structure.

The next phase entails the crucial process of monetising the defined outcomes, a pivotal aspect of the SROI analysis. In the case of the Santa Marta Student Housing, significant effort was dedicated to identifying indicators closely aligned with the outcomes. While enhancing accessibility to the right to education stands as a primary social objective, other outcomes of substantial social significance for each stakeholder were also identified. Specifically, the indicators utilised in the impact identification phase are detailed in Table 1.

Some indicators will be quantified through specific measurements, such as the number of employees in the new facility, the number of new Wi-Fi users, and the square meters of new green areas. For other indicators, such as students' increased sense of independence, enhanced feeling of security, and improved social relationships, interviews will be conducted. Additionally, some indicators will be estimated through proxies, such as reduction of public transport subscriptions, and the increase in service activities in the neighbourhood.

Ultimately, after identifying the indicators for each outcome, the SROI methodology requires finding a financial proxy to quantify the project's importance concerning these

Table 1. Impact values of the case study.

Step 1	Step 2	Step 3
Stakeholders	Outcomes Description	Value
On whom do we have an effect? Who has an effect on us?	How would You describe the change?	How would You measure the change?
Students	Accessibility to the right of study	Savings compared to the rent if they had used private apartments
	Increased reputation in the university	Increase in enrolments
	Access to Internet	Wifi new accounts
	Increased sense of security and improved social relationship	Quality of life
Erasmus real estate fund	Construction of a student-residence without using the public budget	NPV, IRR, ROI
Local Community	Impact calculated on the basis of sales of services, bar, laundry, grocery	Increased activity in the neighbourhood
	Increase in property values due to the urban renewal	Trend in market values of the area
	Increase of public spaces	Sqm green area
	Direct impact calculated on the basis of the jobs created and covered by residents	Wages
Transports	Decrease in commuting within the city	Time reduction on the boat stops
Society	Reduction in energy demand and CO_2 emissions	kWh/m^2·y, CO_2

indicators. This entails monetising the indicators, marking the culmination of this part. Introducing the parameters of deadweight and attribution is pivotal at this point. Deadweight aims to evaluate the extent of change that would have taken place even without the investment under consideration. Hence, the ultimate goal is to ascertain the SROI of the Santa Marta project using the following formula:

$$SROI = \frac{Economic,\ environmental\ and\ social\ value\ created}{Investment\ Costs} \tag{2}$$

6 Conclusion and Future Perspective

The aim of this study was to formulate a methodological framework for evaluating the economic and social components during the feasibility phase of Public-Private Partnership (PPP) projects, with a focus on incorporating ethical considerations. The selected case study, the construction of the Santa Marta residence as a PPP investment by the Erasmo Real Estate Fund, concentrates on enhancing the value of Italian public assets under PPP agreements. This represents an initial step in constructing a methodological framework to assess both the economic and social aspects of ethically-driven investments, particularly in social housing, such as student accommodation. While traditional financial instruments like DCF can analyse returns and profitability for investors, this study introduces a more comprehensive approach. The SROI analysis, a synthetic measurement model and economic mono-criterial method, aims to identify and monetise the social value generated by the project. The integrated SROI analysis in this study assesses the social impact, quantifying how much returns in social terms can be attributed to every euro invested. By delineating the stakeholders, identifying impacts, and establishing measurement metrics, a social value for the economic initiative within the neighbourhood can be defined. This acknowledges the dual nature of the investment, which aligns with both social and economic return objectives.

The method described here consists of three analyses: (1) Economic and financial; (2) Environmental; (3) Social. The methodology thus defined may therefore represent a useful support tool for decision-makers in urban spatial planning processes.

Future research developments concern, first, applications to case studies to test the approach. In addition, the methodology can be extended to other case studies in different parts of Italy. In conclusion, this study serves as an initial exploration into the integrated assessment of the economic and social impact of PPP investments. The proposed methodology is envisioned to encourage investors and public administrations to prioritise social impact assessment, ensuring the ethical advancement of public heritage enhancement projects through PPPs.

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Spatial Analysis of Tourism Pressure on Coastal and Marine Ecosystem Services

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Abstract. Coastal and marine environments generate a multiplicity of Ecosystem Services (ESs) critical to humanity. The study provides a partial estimate of the tourism pression on ESs in coastal municipalities in the South of Italy. It develops a series of tests to understand the existence of correlations between the tourist penetration rates (TPR) of each municipality and the tourist extra pressure recorded in municipal solid waste (MSW) production and drinking water consumption in the reference year. The relative results return positive and significant relationships in both cases, but the correlation is higher in the association between TPR and MSW. Further tests substitute tourist density rate (TDR) for TPR, but the variables result non-correlation. Coastal municipalities experience greater increases in tourist pressure on the anthropic and ecological component because of large tourist inflows. Moreover, tourist extra pressure is more than proportional in demographically smaller municipalities.

Keywords: Ecosystem services · Carrying Capacity · Coastal zone management

1 Introduction and Purpose of the Work

Coastal and marine areas generate a multiplicity of Ecosystem Services (ESs) critical to humanity [1]. Costanza et al. [2] and Martinez et al. [3] point out that oceans and especially coastal areas contribute more than 60 percent of the total economic value of the biosphere. Still, according to the Millennium Ecosystem Assessment (MA) [4] marine and coastal ecosystems produce the following services: (a) provisioning, such as fisheries and building materials; (b) supporting, among others, maintenance of the life cycle of local fauna and flora, cycling of elements and nutrients; (c) regulating, e.g., carbon sequestration and storage, erosion prevention, wastewater treatment, moderation of extreme events; (d) cultural, which include tourism, recreational, aesthetic and spiritual benefits.

Therefore, coastal and marine tourism, which specifically encompasses a wide range of recreational and sporting activities that take place both directly in the marine environment and near the coast [5, 6], is to be understood precisely as a Cultural Eco-systemic

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Service (CES). It is an CES that can generate immaterial benefits involving «cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation and ecotourism» [4]. According to Hynes et al. [7], tourism and recreation are among the most valuable CESs, as they are most directly linked to human well-being and can incentivize public support for protection efforts. According to Hermes et al. [8, p. 290], such CES represent «the natural environment's contributions to the range of leisure and recreational opportunities and experiences enjoyed by human societies». Again, in agreement with Liquete et al. [9, p. 6], CESs are «opportunities that the natural environment provide for relaxation and amusement». While coastal tourism is to be understood as a cultural service that produces benefits for human beings; it also becomes a driver of ecosystem change and is inextricably intertwined with the regulatory and supply services generated by the coastal areas themselves [10, 11]. In other words, on the one hand, the current and increasing growth of the touristic sector plays a crucial role in a country's economic development; but on the other hand, it also exerts high pressures on environmental resources, which can interact with other human activities and cause «complex cumulative effects on the marine and coastal environment and their services» [12, 13]. Massive flows of tourists, which are often concentered in relatively small areas, can have enormous environmental impacts on ecosystems and their functionality, intensifying and cumulating with other human impacts from local people's activities: among the impacts of tourism emerge pollution, waste generation, and water consumption [14–16]. Considering that terrestrial and marine biodiversity, the complex mosaic of habitats and landscapes are the basis of coastal and marine tourism attractions, the good functionality of coastal ecosystems is a prerequisite for the persistence of long-term coastal tourism and related economic activities [17, 18]. Therefore, the maintenance of essential ecological processes and the preservation of natural heritage and biodiversity must coexist with sustainable tourism development, that is, one that aims to meet the needs of tourists, considering the needs of the local population, accommodation capacity and the environment [19, 20].

In these terms, it emerges that the establishment of local and national strategies aimed at the conservation of these ecosystems is among the main priorities of the Governments. Indeed, the European Union (EU) has promoted a series of directives that serve as a framework for EU water policy and aim to provide indications to member states on the protection of inland, transitional, coastal and groundwater and marine environments. These include the Water Framework Directive (WFD, 2000/60/EC), the Protocol on Integrated Coastal Zone Management (ICZM) [21], the Marine Strategy Framework Directive (MSFD) [22], and the Maritime Spatial Planning Directive (MSP, 2014/89/EC), which address the sustainable development and management of coastal zones. It is evident that it is necessary to first understand the impact of tourism demand in coastal areas to plan strategies aimed at the conservation of coastal ecosystems and, more generally, sustainable tourism actions; then, to identify the pressures of tourism on ESs and human activities; and finally, to economically assess coastal and marine ecosystem services, including CESs. This study takes as its framework the reflections between ecosystem functions of coastal spaces and spatial distribution of tourist pressure. Tourist pressure is analyzed through correlation estimates that associate, from time to time, municipal rates of tourist exposure with the *extra pressure* on municipal solid waste (MSW) production and drinking water consumption recorded because of the amount of tourist inflows. The article is organized as follows. First, the survey methodology related to the selection of indicators and construction of variables for correlation estimates is described. The estimates assume municipalities of the Southern Italian regions as the unit of analysis. Second, the results obtained from the different correlation tests are proposed and then, evaluated and discussed through systems look.

2 Methods

Correlation tests return information on the pressure exerted by internal tourism (domestic tourism and inbound tourism), in terms of the impact of the tourist movement on urban waste generation, the water resource and the anthropic-territorial component. The database is based on secondary statistical sources and assumes the 2,551 municipalities of the Mezzogiorno as the unit of survey.

The study computes a tourist penetration rate (TPR) and tourist density rate (TDR) for each municipality [23–25]. The TPR returns the average daily number of overnight stays per 100 inhabitants; the TDR returns the average daily number of overnight stays as a percentage of municipal area. The rates obtain a measure of a territory's tourism exposure and are both used as measures of the intensity and distribution of tourism pressure on the anthropic-territorial component. The elementary indicators underlying both rates are made available by the National Institute of Statistics (ISTAT) [26]. Specifically, data on resident population and the area of municipalities (in sq. km) refer to the year 2021; the internal tourism, expressed in terms of overnight stays (of residents and non-residents) in the total non-submerged accommodation sector [27], is imputed to 2019. The flow imputation interval coincides with the peak year of the internal tourism detected for Italy by ISTAT [28], the data are thus made neutral with respect to the disruptive event of the Covid-19 pandemic.

The *tourist extra pressure* is calculated by constructing partial measures of ecological-environmental tourism load. The measures are derived from the sustainable tourism valuation frameworks proposed in the literature [29–36]. The first and third correlation hypothesizes associate TPR and TDR, respectively, with a first partial dimension of ecological-environmental tourism load. The dimension is identified by the municipal solid waste (MSW) component and the relative *tourist extra pressure* observed in MSW production because of the number of overnight stays registered at the municipality level. The dimension is composed of three elementary indicators: the inhabitants in the municipality (resident population, ISTAT 2021); the floating population in the municipality (tourism night of residents and non-residents, ISTAT 2019); and the total amount (in kg) of MSW produced in the municipality in the year 2019 (ISPRA, 2019).

The component MSW is obtained from the municipal waste (MSW) databases of the National Institute for Environmental Protection and Research (ISPRA) [37]. The municipal wastes are given by the summation of a wide range of waste products from the domestic sphere (premises and places used for civilian use), commercial and industrial activities, and institutions. They include undifferentiated and separated waste fractions collected in the municipal area.

The second and fourth correlation hypotheses associate TPR and TDR, respectively, with a second partial dimension of ecological-environmental tourism load. In this case, the size is identified by the competent of water demand for drinking purposes and the related *tourist extra pressure* on the volumes of water delivered because of the number of overnight stays registered at the municipality level. The construction process is similar to the previous one, but replaces the MSW component with the total volume (in liters) of water delivered by municipal drinking water distribution networks in the year 2018 [26]. Statistical information on the volumes of water delivered is provided by ISTAT and released occasionally from the civil water supply chain and water services management surveys. The year 2018, in the absence of the 2019 figure, is considered for consistency opportunities. In detail, this indicator considers the sum of volumes of water for potable use consumed for authorized uses (public uses and private uses) [38].

So, the development of partial dimensions of ecological-environmental load bases on the comparison of different calculation methodologies. A first methodology [39, 40] estimates the contribution of tourism nights on the tourism load in MSW production and volumes of water delivered for potable use as the product between the total average production (consumption) per person-day and the number of tourism nights. A second methodology [41] estimates the impact of tourism on the components in terms of average per capita daily consumption. We assume for the construction of the dimensions, as suggested by the first methodology, that residents and tourists are characterized by similar consumption and production patterns [39]. We take from the second methodology [41] the procedure for calculating the impact of tourism on the components, due to the daily per capita measure. In the work the result of tourist extra pressure for each municipality is obtained as:

$$\frac{Total\ dimension\ value}{Resident\ population} - \frac{Total\ dimension\ value}{Resident\ population + (\text{nights spent}/365)} \tag{1}$$

In a first case, we calculate the difference between MSW production per capita (kg/inhabitant) and the ratio of total MSW quantity to residents summed with tourism night apportionments in the year; in a second, the difference between potable water consumption per capita (l/inhabitant) and the ratio of total volume of water delivered for potable purposes to residents summed with tourism night apportionments in the year.

3 Results and Discussion

The impacts of tourism, particularly in mass destinations and characterized by seasonality, induce the existence of diseconomies, primarily environmental and socio-anthropic [42–44]. In fact, at the destination or locality level, the increased pressure exerted by the concentration of internal tourist flows at certain times of the year leads to increased load on environmental resources, waste production and the consequent increase in demand for services related to waste recovery/disposal in specific treatment facilities [45–47]. In some areas of the coastal South, tourism growth has triggered a radical process of landscape transformation. In fact, as also noted internationally, the tourism sector has often been considered a strategic sector for promoting economic growth. Compared to the inland South, coastal areas describe intensely urbanized and sealed areas [48, 49].

To date, coastal municipalities account for 59 percent of the total southern population (continental and insular) and serve in the macro area as the main destination for tourist inflows, tourist arrivals and tourist overnight stays [26]. The increase in tourism implies the need to meet proportionately higher urban demand, which, in the absence of efficient or undersized services, results in a greater burden on coastal ecology.

The first correlation test (Fig. 1) shows a positive and significant relationship between the level of tourism penetration (TPR) and the level of the incidence of overnight stays on the increase in MSW production. The value of the R-squared coefficient is 0.91. According to this estimate, the marginal increase in the average daily number of tourist overnight stays results in a more than proportional increase of the tourist load on the anthropic-territorial and ecological dimension per tourist per day in the locality.

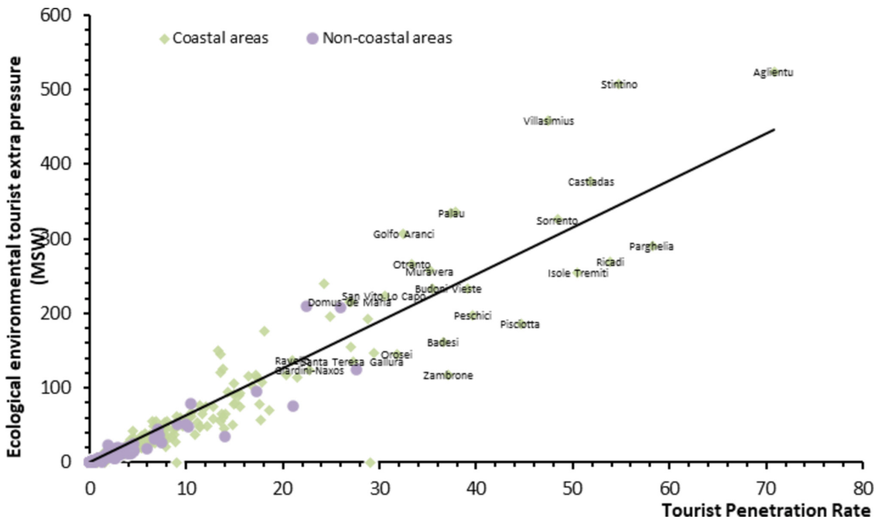

Fig. 1. Correlation curves between Tourist Penetration Rate (TPR) and Ecological environmental tourist extra pressure (MSW component) at municipal level (our elaboration).

The measure finds empirical evidence when comparing municipalities of different demographic size. For example, the municipalities of Aglientu (1,168 inhabitants), Positano (3,772 inhabitants.) and Catanzaro (85,609 inhabitants), detect shares of overnight stays in accommodation establishments of 302,029; 334,220; 144,182, respectively. In this case, the highest values in the average daily per capita production of MSW attributed to tourist movement is 524.4 kg/day per tourist in the first municipality; 239.1 kg/day in the second municipality; and 1.2 kg/day in the third municipality. Similarly, in terms of TPR, the average daily rate is 70.8 overnight stays per 100 inhabitants in the first municipality; 24.3 overnight stays per 100 inhabitants in the second municipality; 0.5 overnight stays per 100 inhabitants in the third municipality. The coastal region registers the highest levels of anthropic-ecological tourism load. Consistent with the previous result, the municipalities represented at the top of the correlation graph constitute demographically smaller LAU-level coastal areas. This group shows the presence of locations with a strong tourist traction such as the municipalities of the Gallurese coast, in the northeastern part of Sardinia, in the province of Sassari [50, 51]; the municipalities of Tremiti Islands (island municipality), Vieste and Peschici in the Gargano National Park, in the province of Foggia [52]; Zambrone, Ricadi, Parghelia in Calabria, in the maritime stretch of the province of Vibo Valentia. The daily tourist load has implications that are reflected in the need to cope, at given times of the year, with the increase in water demand induced by increased overnight stays. Gössling [34] attributes additional water demand to different uses of the water resource. In this sense, the *tourism water footprint* is to be found in both direct and indirect uses of drinking water, so it is to be estimated along the entire tourism supply chain (ibid.). Among "tourism-oriented" economic activities, accommodations represent a critical component of drinking water consumption; this depends on the typological category of the accommodation facility [53, 54]. In many tourist locations in the South of Italy, especially in places that have become seaside tourism destinations, the process of coastal littoralisation has been accompanied by the now established phenomenon of second homes and intensive vacation construction.

The pressure exerted by tourism in terms of drinking water consumption results in both upstream and downstream burdens in the water service management chain. The water needs to be addressed are noted in the services of supply and distribution of water for drinking, sewerage and urban wastewater treatment. In the Mezzogiorno, faced with the existence of spatially concentrated tourism especially in the hot season, the increased demand for water highlights the emergence of critical environmental and ecological issues. This may relate to water supply levels during periods of greater drought, the use in the high season of additional water sources to cope with oversupply thresholds, and the functional effectiveness of wastewater treatment systems. In this case, the increased tourist load associated with management and infrastructural dysfunctionalities of the water system potentially contributes to reduced bathing water quality and the overall status of the aquatic-marine environment. ISTAT [38] notes the existence of a North-South gradient in distribution water losses because of territorial and infrastructural differences, with peak values in 2020 in Sicily and Sardinia. According to the institute (ibid.), the adoption of water rationing misures invest especially in the South; of the 296 municipalities in which water purification service is absent, 67.9 percent are in the South, particularly in Sicily, Calabria and Campania where there are plants that are often under sequest, being modernized or under construction. Overall, in Italy out of 1.3 million residents not covered by public sewage service, the mainland Mezzogiorno accounts for 30.7 and the Islands 48.0 percent; out of the total 387,000 resi-dents without public sewage service, the incidence is 9.8 percent and 81.4 percent, respectively.

The second correlation test (Fig. 2) shows a positive and significant relationship between the level of tourism penetration (TPR) and the level of the incidence of overnight stays on the increase in water demand. But, in this case the R-squared coefficient is 0.8.

The marginal increase in the average daily number of tourist overnight stays results in a more than proportional daily increase in anthropic pressure and additional water demand per tourist per day for the destination municipality. The more than proportional increase is again confirmed by the municipality's smaller population base. In fact, the municipal comparison shows, in proportion, the existence of a higher tourist load on the water component for the municipality of Aglientu equal to 100.8 l/day; lower for

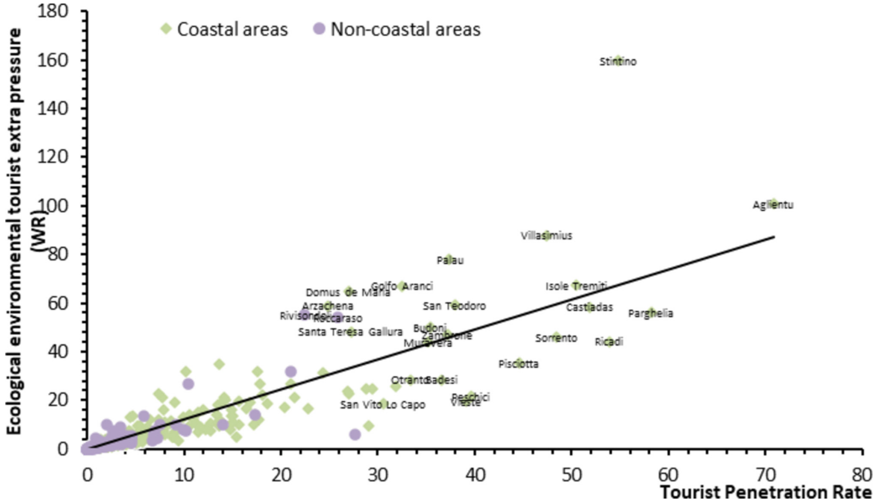

Fig. 2. Correlation curves between Tourist Penetration Rate (TPR) and Ecological environmental tourist extra pressure (water resource for potable uses component) at municipal level (our elaboration).

Vieste 19.4 l/day (13,434 inhab.; 1,915,749 overnight stay); very low for Catanzaro 0.4 l/day. While the TPR in the municipality of Vieste is 39.0 overnight stay per 100 inhabitants. Anthropic and water load because of tourism is again observed especially in the municipalities of the coastal South. The value of the correlation is relatively lower in this second estimate than in the previous test. The third and fourth correlation tests aim to search for the existence of an association between the average daily tourist density, indicated by the TDR, and the average daily load increase per tourist on the MSW and water demand components, respectively. In both cases, the results provide no correlation. It is possible to assume, therefore, that the smaller land area per se is not sufficient to justify the increased load on both components. But that, conversely, it is the degree of population size that is more significant. This finding is returned by previous estimates of correlation with the TPR. To this end, we detect in the TPR an explanatory variable for monitoring the tourism pressure exerted on an area and the sustainability of tourism growth on a local scale. At the same time, combining the TPR with additional indicators contributes to the implementation of detailed analyses of the effects of tourism on ecosystem services.

4 Conclusion

The increased impact of tourism on smaller towns in the coastal South confirms the need to monitor in coastal spaces, from a sustainability perspective, the link between tourism and ESs. Coastal and marine environments plays a critical role in the relationship between the ecosystem and the economic system. The coastal tourism space is a complex system in which a multiplicity of recreational and touristic uses act simultaneously [5]. Looking at destinations, the increase in hikers and tourists is intertwined with their parallel increase in urban demand [55]. This "external pressure" [44] has its own spatial, environmental and economic impact. In fact, the competitiveness of a coastal destination and its respective tourism industry largely depends on its ability to conserve the ecological resources of coastal and seaside environments.

Moreover, some limitations of this study must be noted. The estimate does not take into account the so-called calendar effect. It is plausible that coastal destinations characterized by higher seasonal concentration of flows, in the absence of planning interventions aimed at ecological resilience, would detect higher levels of tourist load in high season. In addition, the study did not consider the additional spatial load entailed by hikers. The inability to count hikers, of visitors who do not result in an overnight stay, resulted from the impossibility of collecting statistical sources at a municipal level of detail. The study offers only a partial look at the tourist load on coastal and marine SEs. Indeed, it has already been noted that TPR is shown to be an explanatory variable of an area's tourism exposure. The systemic information provided by the TPR should be complemented with the additional misures offered by the assessment and monitoring frameworks [39, 40] applied to estimate, overall and in a transcalar perspective, the sustainability of tourism. At the same time, correlation tests based on TPR and partial measures of the ecological-environmental tourism load, considered as the tourist extra pressure on MSW production and drinking water consumption, provide useful evaluation elements to understand the geographic distribution of the factual impacts of tourism on localities. Therefore, this study contributes to the potential implementation of tourism spatial planning tools at the system scale. So, the relationship between geographic studies and estimative studies opens up further research perspectives, related to: geospatial analysis of threats generated by tourism and other human activities on coastal and marine SEs; economic evaluation of SEs in order to provide policy makers with trade-offs and synergies related to ecosystem management of marine and coastal environments; and Cost-Benefit Analysis (CBA) of projects for alternative management of areas of tourism and environmental value.

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Smart Tourism Development in the Peripheral Areas: The Opportunity of Startups

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Abstract. Smart Tourism is a concept that has catched the attention of several researchers in recent years. However, there are still few studies on its application in non-urban contexts. This paper focuses on the corporate component of smart tourism and the role of tourism start-ups for the territorial innovation processes in peripheral areas. To support the analysis, the authors present a case study of a start-up tourism-oriented located in the peripheral area of Alta Irpinia (Campania region, Southern Italy). The study highlights how tourism start-ups play a critical role in the development of different types of innovation. The start-up's contribution to these innovation processes involves both its technical components and its relationship dimension. The latter makes use of the active participation of the community, institutions and the academic world to generate territorial innovation processes. Innovation in the field of tourism is understood as an open process developed on the flow of knowledge generated by the interdependence between business, local community and tourists.

Keywords: Smart Tourism · Internal areas · Sustainable Tourism

1 Smart Tourism: A Conceptual Approach

Smart Tourism (ST)[1] is a concept closely linked to the large-scale use of the Information and Communication Technologies (ICTs) and smart technologies in tourism [1, 2]. ST is a term that includes destination (smart destination), behavioural (smart experience) and business (smart business) components [1]. The concept is operationalized through experimental frameworks that assume the use of emerging technologies capable of integrating the physical with the digital world. These technologies include the Internet of Things (IoT), location-based services (LBSs), artificial intelligence (AI), blockchain technology, augmented reality (AR) and virtual reality (VR).

Emerging technologies, based on complex integration and interoperability systems, are interpreted in the ST as infrastructures aimed at facilitating the introduction of process

[1] The work is the result of a common reflection of the authors; nevertheless the single parts can be attributed as follows: Vincenzo Esposito, paragraphs 1, 4; Nadia Matarazzo, paragraphs 2, 3.

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innovations in the fields of tourism management and tourism development [3]. At the destination level, value is co-created by the interactive relationships of several stakeholders [4, 5]. The behavioral component integrates a reading centered on the tourist/user and his active role within the ST ecosystem. Smart tourists exploit the potential of technology to discover content and tools, but also to improve and communicate their experience. It is fair to say that smart tourists consume and produce data about their experience during all phases of the trip. This happens, for example, using social media and other specialized web platforms. On the other hand, the business component offers qualified services that support innovation processes (such as data analytics, cloud computing and geotagging), co-creates content and helps the diffusion of tourism resources within the ecosystem.

The ST component of the destination emerges in the context of smart city studies [1, 4, 6, 7]. Smart cities interpret the urban environment as a complex system of innovation acting equally in the domains of governance, economy, mobility, environment, living and human capital [8, 9]. The convergence of the two models led to a new conceptual framework and the introduction of the term Smart Tourism Destinations (SDT). The primary role of a SDT is to incubate the competitive capacity of the destination while empowering the tourism experience [6]. But furthermore, drawing on the theoretical dimension of Smart Cities, it integrates an approach that recognizes tourism as an integral component of territorial planning; it also considers the coexistence between technology and sustainability, understood in its triple meaning (social, economic and environmental) [10–15]. According to Boes et al. [4] within the ST/SDT ecosystem, the intertwining of ICT with the components of innovation, social capital, human capital and leadership allows to obtain a competitive advantage and an improvement in the quality of life. In Cavalheiro et al. [5] a STD should have, among its objectives, that of creating public value for the host community.

Other applications of the ST concept involve the use of technological systems to limit overtourism. Intelligent solutions were considered a useful operational tool to make tourism space management more effective at system level [16, 17]. The literature has attempted to explore the application of the concept of ST also in contexts that are not strictly urban [18–21]. It has been noted that there are still few studies on smart tourism in rural areas [19]. Indeed, as observed by Gretzel [22], there is an urban bias in the ST concept that limits its application within other types of destinations.

Both on an international and European scales, reflection on the generation of ST/SDT ecosystems outside of urban environments, with particular regard to rural and peripheral areas, has found further impetus within the foundation of Smart Villages (SV): they represent models of intelligent specialization (multi-activity on a small scale) centered on the place [23, 24]. Their primary objective is to reduce the conditions of spatial peripherality (and marginality) through systemic solutions adopted to act on potential territorial capital [25]. Therefore, attempts have emerged to apply the SV concept to advance possible strategies aimed at promoting the local economy in rural and peripheral contexts through tourism diversification policies addressed at the product/market level.

In Italy, the territorial policy called “National Strategy for Internal Areas (SNAI)” identifies internal areas preliminarily in their distance from the centres/poles offering essential services [26]. Internal municipalities are places where varying levels of spatial distance/peripherality (compared Pole municipalities) compromise the full enjoyment of citizenship rights (education, health, rail mobility) by those living there [ibidem]. Internal SNAI's areas include 1,697 municipalities (in total there are 4,059 municipalities in the Internal Areas in 2020), classified according to the degree of urbanization 89% of the internal areas are rural areas while 11% are small towns and suburbs [27, 28]. From the analysis of physical characteristics, a large proportion of the SNAI municipalities fall within the inland mountain (60 per cent) and inland hill (28 per cent) areas respectively. In terms of relative composition, rural areas correspond to 89% of the category of internal municipalities classified as "Intermediate" (up to 40 minutes' car journey to the nearest Pole); 86% of those classified as "Peripheral" (up to 75 minutes' car journey); 97% of the category of "Ultra-peripheral" (more than 75 minutes' car journey) [26–28].

Before Covid-19, tourist flows in these areas exceeded 3.6 mln arrivals and 13.3 mln overnight stays [29]. In 2020, in spite of the drop in national and international tourism, the Internal Areas, especially the Ultra-peripheral ones, recorded less variation than the centres in the number of overnight stays and arrivals [30]. Looking at the data to 2020 on the amounts financed by sphere of intervention in the 71 Area Strategies, actions related to tourism absorb 18% of the total resources, the highest percentage out of the total of interventions for local development [31, p. 25]. Many of these areas have comparative advantages in terms of cultural, natural and landscape heritage. To this end, this study elaborates on the experience of an innovative startup based in an internal area of the province of Avellino (Campania, in the Mezzogiorno macro-area). The startup promotes participative development actions in the field of tourism, territorial regeneration and urban regeneration [32–34]. It will be discussed how innovation in tourism (and in local development action) is understood by the startup as an open process based on the flow of knowledge generated by the interdependence between business, local community and tourists.

2 The Opportunity of Startups: A Case Study in Southern Italy

Competing in a global market is the *conditio sine qua non* to come out of isolation by developing a smart tourist industry where technological innovation and environmental sustainability are the two fundamental pillars. About this, the role of the startups is strategic. They concern not just the firm's early stage, but a business with a high potential for growth and development. In this phenomenon, especially, innovation represents an important factor. Unlike traditional businesses, startups can grow quickly, operating and dominating the industry at an international level, taking advantage of Internet opportunity. Many relevant inputs can be found online, including venture capital and partnerships.

However, the diminishing need for stakeholders to stay in a limited spatial distance raises the possibility for rural regions to become interesting for innovative startups with high growth potential. A rural region, instead of being understood as remote, should be understood as a dynamic entrepreneurial resource that shapes both opportunities and constraints [35]. Rural entrepreneurship engages with the location and thus provides additional value by leveraging local resources. Nevertheless, knowledge spillovers are one key determinant for entrepreneurial activity and rural regions mostly lack institutions such as universities or research institutions that could generate spillovers, but firms especially benefit from employees that worked or studied outside their home region. In addition, for startup formation the relocation of founders and the acquisition of knowledge from other regions increases not only the propensity to start one's own company but also its survival rate (*ibidem*).

One solution to avoid the problem of missing knowledge spillovers would be to motivate a startup founder to move back to their home region, they would have a good chance to survive. This happened in several peripheral and rural regions during the pandemic of Covid-19, when several workers became very flexible concerning their workplace and came back home in order to live more comfortably during the lockdown period (larger houses with gardens, spaced settlements and so on). This transfer of expertise, although forced, played together with the increase in demand for slow and green tourism also recorded following the pandemic, favoring the birth of startups for the territorial and tourist promotion of "minor" territories. This was what happened in Irpinia, an internal land of Campania, province of Avellino (Fig. 1), where in 2020 a little group of young professionals founded *Visit Irpinia Srl Innovative Startup.*

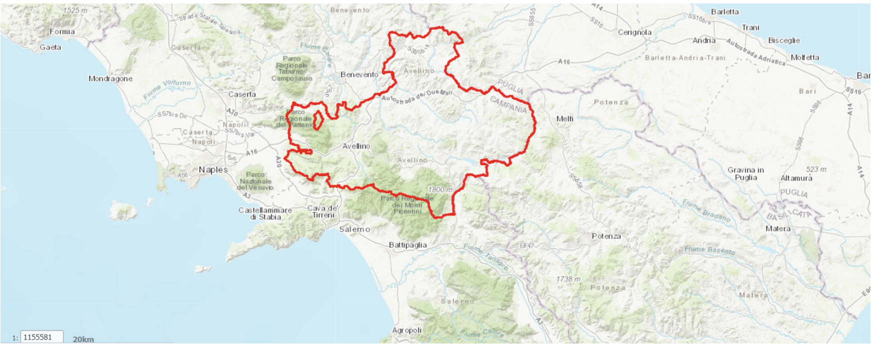

Fig. 1. The Province of Avellino (Irpinia). Source: Province of Avellino [36]

The mission of Visit Irpinia is a new and complete communication of a territory perceived as peripheral on a regional and national scale, matching knowledge and innovation, enhancing local attractors in the broader regional context, with particular attention to distances and mobility, the accommodation supply, the calendar and seasonality. During three years of activity, this startup is implementing a dynamic and multimedia atlas of local territories, contributing to position Irpinia as an attractive product, in the plurality of its identities, on the global market of destinations to visit.

Not a simple showcase of the territory but a digital hub in which material and immaterial merge to provide the faithful story of this uniqueness, an experiential, free and multifaceted map, continuously updated. A digital platform that connects places, seasons and flavours, which will allow the traveler to build their own personal journey. Several technologies have been used to apply innovation to rural tourism development: augmented reality, short-ray communication systems such as Bluetooth and WiFi, interactive kiosks, cloud computing platforms to concentrate huge quantities of data and their processing. These tools can permit the tourists to represent/describe/interact with the tourist site in a fluid space-time dimension trough a multi-way and multichannel approach which imply the simultaneous use of different mobile devices.

The most recent project of Visit Irpinia is a civic crowfunding, that is a method of raising funds from a community for the fulfilment of civic initiatives, in this case the regeneration of an abandoned railway station. The strategy is to connect places requalification and tourism with the place-based dimension of a civic crowdfunding campaign. The follow-up of this study will be to show how giving new life and new functions to an old railway station can attract tourists, increase the numbers of funders, as well as attract the interest of the municipality, not-for-profit associations and tourism firms, and thus significantly enhance its beneficial effects on sustainability from economic, social and environmental points of view.

3 Tourism Development in Peripheral Areas: Critical Considerations

A pillar of the debate on the peripheral areas is that which concerns tourism, considered one of the fundamental, if not the main, development trajectory, despite many contributions - including the Italian National Strategy for Internal Areas (SNAI) programmatic documents - stating otherwise. The founders of the Italian association “Riabitare l’Italia”, for example, criticizes that approach to heritage development based on a consideration of peripheral and internal areas as a simple deposit of resources, while the need for a new vision of heritage is supported: its focus does not fall on the availability of naturalistic or historical and cultural assets, but rather on the ability to build habitability paths [37]. On the contrary, the recent policies orientation runs towards touristification: since 2017, a paradigm centered on the internal areas was launched, based on experientiality, presumed authentic contact with local communities and immersion in territorial traditions [38]. A kind of proposal empowered by the pandemic of Covid-19.

This perspective, which the National Plan for Recovery and Resilience essentially also refers to, generates, however, a polarization between territories endowed with resources - landscape, experiential, food and wine - which give them attractiveness on the tourist market, and those which will have to work hard in order to find (or invent) elements to characterize their assets for the purposes of monetization. If this seems to support the success of some territories despite the other ones, it will become unsustainable even for the “awarded” territories themselves, because the development drawn by tourist monoculture generates economies, whose life cycle depends on tourist use and not, as it should be, on an internal empowerment process [39].

In fact, for tourism success to trace a path of continuity, it is necessary for local communities to play a leading role, who must be accompanied to integrate tourism into their usual context of life and involved in a strategy capable of promote the identity of the territory without diminishing or transforming it (ibidem). This approach leads to focusing action on the potential of heritage to trigger an effective process of territorial regeneration in which the local community is the protagonist, as a subject capable of planning and promoting its own future [40].

The peripheral areas cannot, therefore, be handed over to the tourist injection, because this would constitute nothing more than a filling, moreover extemporaneous, and consequently no repopulation at all. In this sense, it is also appropriate to dare some critical considerations on the risk of *museumisation* of these territories, for which the strengthening of tourism is co-responsible: the culture, now widespread, which identifies in the policies of protection and conservation of the tangible and intangible heritage of small municipalities of an internal area, an indispensable act for local development, lends itself to being interpreted, on the contrary, as the definitive passage towards the devitalization of these territories, whose most widespread and deep-rooted perception is that of sanctuaries to be protected and contemplated. According to the geographer Varotto (ibidem), the establishment of the Parks in 1993 also responds to the logic of *museumisation* and the exaltation of empty spaces, which he considers functional to compensate for urban obesity but completely imaginary, since - he states - the spaces they are always full when considered in their environmental, social and cultural dimensions (ibidem). On the other hand, the presence of a protected area, characterized by a strong recognition, can be of value for territorial promotion and in many cases, the relationship between protected areas and tourism destinations is mutual. Tourism is an important resource for natural parks because the modern tourist tends to positively assess landscapes, symbiotic nature-agricultural activities, nature-based lifestyle and natural heritage [41].

Varotto's analysis, aimed mainly at the mountains but also useful for interpreting the question of internal areas more generally, is placed in that line of critical studies, which propose a revision of the policies aimed at the repopulation of the marginal territories which hinge on digitalization of work, tourism and social innovation. In fact, they are based on the belief that increasing the population in some way can free these places from economic suffering, when, in reality, they will no longer be inhabited if the number of residents simply increases: it is not sufficient to measure abandonment, in fact, with the merely quantitative criterion of demographic contraction because this does not allow us to understand that abandonment is, in reality, the "end of living in the mountains" [40, p. 61] - and, by extension, in internal areas - that is, the disposal of a social and cultural model to which a specific type of relationship between man and the environment is connected, to reproduce which a strategy that goes well beyond mere repopulation is necessary.

4 Conclusion

The study attempted to outline the contribution of an innovative start-up within a specific peripheral context. The ST ecosystem implies an intensive use of technologies and the existence of a destination capable of incorporating innovation and encouraging the meeting between supply and demand. In particular, in rural and peripheral contexts the impact of digital must take into account tourism businesses characterized by low technological content and traditional production models that operate on a small scale [42, 43]. On the other hand the study by Sedmak et al. [44] suggests how the perceived benefits of the use of ICT by managers, potentially younger and more educated ones, positively influences the performance of rural tourism businesses.

The start-up, in line with the literature, operationalized the ST concept through a complex set of initiatives that acted at a system level. In the case observed, the hard infrastructures and specialized skills within the company were integrated with the enhancement of the relational dimension with the aim of generating value through local networks of territorial cooperation. In this sense, the technologies rather than the purpose are interpreted as the means of transmission of the local network [45].

The latter makes use of the active participation of the community, including institutions and the academic world. Innovation in the field of tourism is understood as an open innovation process that develops on the flow of knowledge generated by the interdependence between all subjects. The internal organizational structure of the company merges with the social capital to understand and mobilize resources (local or external) for the development of different types of innovation.

The destination/territory becomes a cohesive space used by the start-up to increase its competitiveness; at the same time, an ethical role of the company emerges towards tourists and the local community. On the one hand, the tourist experience becomes an experience of the territory for the consumer. Here the technological potential was interpreted as a vehicle to break down the barriers between the tourist, the places and the community. This was observed, for example, in the ST projects carried out by the start-up in the field of cultural tourism, read in terms of traditions and creativity, and in the union of this with other tourisms of particular interest (rural tourism, agritourism, hiking tourism) characterized by markedly experiential contents aimed at making known the value and socio-cultural characteristics of the product/service. On the other hand, the company rediscovers its own ethical role towards the local community.

Furthermore, the start-up acts to encourage the exchange between the economic and social dimensions in order to guide the development of projects that involve local businesses/institutions/ local community in territorial regeneration processes. The reuse of urban spaces and derelict buildings in marginal territories acts as a critical dimension for the potential generation of economies.

Future work will aim to extend the analysis by adopting a multiscalar perspective. The survey will aim to investigate the relationships that are established between tourism start-up and the territories in which they operate in order to identify the existence of common elements among the different experiences.

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