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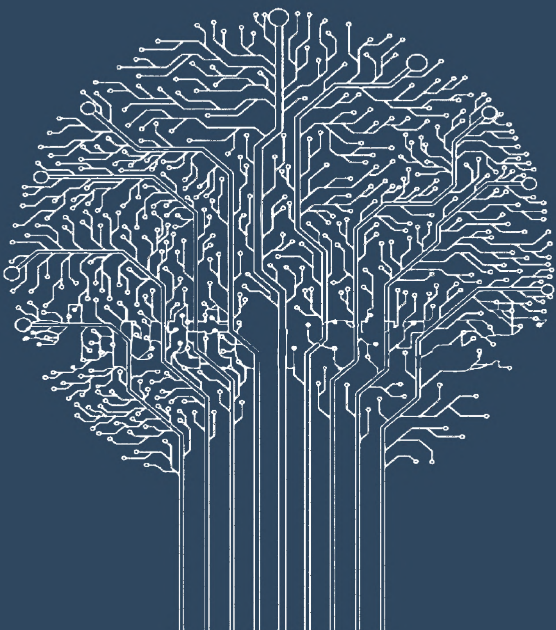
ON SUSTAINABLE BUILT ENVIRONMENT

BETWEEN CONNECTIONS AND GREENERY



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7

ON SUSTAINABLE BUILT ENVIRONMENT BETWEEN CONNECTIONS AND GREENERY

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CONSIDERATIONS AND RESEARCH ON SUSTAINABLE AND CONNECTED BUILT ENVIRONMENT

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Volume no. 7 of the series Project contains essays and critical considerations, research and experiments, projects and actions addressing the subject ‘connections’ between people, between people and things/places and between things/places and ‘greenery’ in symbiosis with the built form, two topics of pressing relevance. Concerning the first subject, we can just remark a profound transformation, a pervasive widespread transition which combines dichotomies (analogue and digital), enhances oxymorons (artificial intelligence), overturns axioms (ubiquity), creates paradoxes (sharing economy) involving, without distinction, architecture, humanities and social science, anthropology, sociology, ecology, biology, physical-mathematical sciences and neuroscience whose impacts will become even more striking in the medium and long term. Although they are currently visible and accelerated in part by the global health emergency. A certainly ‘digital’ transformation, which scholars such as Floridi (2020), Galimberti (2020), Haraway (2018), Searle (2017) and Chomsky (2011) have placed above all on an ontological and epistemological level as it involves the essence of ‘things’, the way we define them, the world around us and in particular our relationship with the elements that constitute it. Therefore, the nature of things and the relationships that connect them are some of the great issues that digital transformation is ‘imposing’ today. They are also introducing innovative approaches and actions to solve both ‘historical’ and new problems (anticipating systems, possible futures, etc.) and new inconveniences (exclusion, digital divide, etc.), claiming the ‘vitalism’ by the current cultural, social and economic challenges that influence the contents of Agenda 2030 and the involved principles of sustainability, innovation and social justice issues. In fact, we are shifting from a reality made up of things to one characterized by relations – connections – moving in a daily reality made up of intangible ‘objects’.

Physicality/materiality and history of forms also become virtual realities by mixing in the immaterial flow of networks and deterritorialised flows: the digital ‘opens’ by connecting (delocalizing) and ‘confines’, but above all, it ‘induces’ new spatial configurations in a constantly evolving relationship between genius loci and shape, function and flexibility of use, between the Vitruvian man, and his physical proportions, and the ‘inforg’ man who lives, works and relates to the contemporaneity of simultaneously physical, virtual and digital places. A space that, as an ontological entity (natural, built, joint, open, secured, connected, residual, interstitial, on a macro or micro or nanoscale, no matter if we are talking about surfaces, volumes, thresholds, technical-construction/plant components and objects) in any form (from landscape to territory, from infrastructures to cities, from buildings to objects, up to systems, components and materials) expresses Connections: Physical, in the single material, analogical and tangible object; Virtual in configuring experiences of augmented and immersive reality, of wearable technologies; Digital in interacting and implementing new creative and communicative processes and, at the same time, technical, to control and monitor the project at various scales, conveying forms and images, functions and performances in a new dimension of digital sharing.

The relevance of the second subject is linked to deforestation and forest fires, urban sprawl, indiscriminate use of non-renewable raw materials and an increase in CO_2 emissions contribute to global warming and climate change, causing a devastating impact on our fragile ecosystem, society and the economy. Once it was established that we will not reach independence from fossil fuels (maybe) before 2050, we recall the role that nature and greenery in general can play in the short term to address the current challenge that threatens the whole planet. This was already highlighted by Beynus studies (2002). They are a knowledge heritage useful for the regeneration, with awareness and responsibility, of the built environment. Over the millennia, Nature has perfected strategies and solutions, processes and mechanisms to adapt to different climates and physical conditions through the rationalization of the use of matter and energy by optimizing material and immaterial metabolic exchanges. Even earlier Simon (1969) had understood the prospective of a 'new ecology' in which the animate and inanimate components of the built environment combine to characterize a 'unified' landscape.

While the Modern Movement has considered landscape, urbanism, architecture and design as separate disciplines, in the new millennium there is a 'scalar shift' in which they are considered as a part of a unified territorial system, in which we are called to design for humans and living beings, in a connection made of profound knowledge and understanding of the trajectories and coexisting needs of the many human and non-human inhabitants of the built environment. The relationship between the parts of the system takes on crucial importance when we adopt a broader and more systemic vision, supported by a holistic and participatory approach (Otto, 2008). Digital technologies can support this 'double convergence' in their shift towards a 'cybernetic ecology' allowing us to see the natural and artificial world as a unicum (Ratti and Belleri, 2020).

Once the classic artificial/natural dualism is overcome, new possible project scenarios emerge, made possible by the potential of computer sciences, bio-engineering, digital technologies, parametric design and 3D printing. They open up to new mediations and intelligence forms borrowed from a multiplicity of living species which define and configure bio-design, bio-architecture, bio-infrastructure, and bio-city solutions. A new systemic, interdisciplinary and multiscalar logic begins to spread: from cyber-gardening to bio-technological remetabolization of whole neighbourhoods, to responsive envelope systems that integrate bio-materials and/or cultures of living microorganisms but also new opportunities for circular sustainability. Greenery and digital technology provide many benefits for environmental, social, economic, health, well-being and quality of life aspects: their 'creative and strategic' approach can be essential for sustainable and aware development.

The five papers in the volume investigating the 'connections between people, between people and things/places and between things/places', with the considerations made by the Authors do not cover all areas and fields of research. However, they delve into some connections in an exhaustive and interrogative way, sparking new interests and knowledge in the reader. Augmented Reality and Virtual Reality, modelling and handling, and digital design are only some of the tools useful to create a network of new connections. The interest in new connections can be found in the proposal of an Augmented Reality app for the Heritage and in the case study on the Basilica SS. Medici in Alberobello. It provides additional support for users in getting to know sacred spaces as they were conceived by their designer, but also through the specificity of Digital Design that, thanks to the ability to foresee future scenarios, helps to understand the possible answers that digitisation can give us on the apparent dichotomy with the sustainable dimension. SMAG and COLUX are the two mentioned case studies. The first one develops a system of products-services capable of monitoring the vital parameters of green spaces; the second designs an innovative platform to create virtual environments of products and housing spaces through Augmented Reality and Virtual Reality.

Some equally interesting pieces of research on the subject of connection were carried out to support the need of specific users living in unique environments, for example, patients and their rooms in a health and assistance centre. Concerning this connection, this volume presents three papers. In particular, one paper deals with the study of spatial/technological organisational models present in a hospital room, trying to combine space flexibility with organisational flexibility to optimise work fluxes in the healthcare processes for operators and the psycho-physical-social wellbeing of all users involved, from the patient to the health worker. The results of this study show that the physical environment can contribute also to the workers' productivity, to clinical, psychological and physical security (as for the prevention of medical errors or reduction of stress factors).

On the Health subject, there are two other papers. The first one is the result of a project developed by the cross-disciplinary group of the Polytechnic University of Milan focused on the subject of digital territorial networks for the valorisation of the territorial impact of the Health Homes in Emilia-Romagna (Italian Region), aimed at defining 'design guidelines' useful to consider Health Homes again as resilience centres, after facing the tragic global experience of the pandemic. The second paper deals with a project focused on the transition towards an increasingly digital Healthcare, recognised by the European Union to improve the access to healthcare, and the quality of care and increase the efficiency of the healthcare system. It is shown that the use of BIM, IoT technologies and ICT applications in the Building Industry can provide important benefits to the implementation of effective design and management processes, revolutionising the design of buildings used to provide care and assistance services.

Although they both aim to search for sustainable, innovative and smart solutions, the two topics of this volume (connections and greenery) have to consider that the contemporary society – better called Sapiens society – is modifying its knowledge and habits because of changes, in which Sapiens is partially accomplice (Butera, 2021). The signs of the need to modify the growth parameters on which industrial societies are based continue to multiply. Over the last years, the debate – often heated between supporters of technological evolution that only aims at the economic well-being of a few people and those who promote happy degrowth – is increasingly compelling (Pallante, 2011). New social life models are growing in Sapiens society, imposed by external factors impossible to ignore: the migration of populations due to famine or poverty; the ever-present wars for control of depleting fossil fuels; the pandemic spread of viruses; climate changes and the resulting pollution and environmental disasters that have accelerated melting glaciers, increasing waste (Armiero, 2021), deforestation of millions of hectares of territory because of unpredictable climate factors, unique for their strength (42 million trees were destroyed in 2018 in the Alpine valleys of Lombardy, Trentino, Veneto, Friuli by 'Vaia storm') or caused by humans with arsons; unbridled urbanisation of coastlines and cities; the indiscriminate use of non-renewable raw materials generating the increase of CO_2. The list could continue, but this description provides a comprehensive overview of the main causes that contribute to making a devastating impact on our fragile ecosystem, society and economy.

The 'greenery' subject is the most extensive part of this volume, addressing with different papers the proposal of strategies for the regrowth and redevelopment of territories, environment, cities, and societies that live in it. These objectives are shared by scientists and scholars. Taking as starting points the European Green Deal and the recent European Taxonomy, the subject of sustainable development is dealt with also by listing guidelines to acquire a method useful to create and express opinions on the green redevelopment of places to be converted into public spaces, the greening of our cities to improve access equity, the distribution and better quality of green areas, the promotion of human well-being and social justice. A research hypothesis on environmental sustainability within building sectors proposes green solutions to make home and building spaces we live in resilient to hot temperatures thanks to the creation of interesting architectonic solutions. A possible solution is making trees part of the building, in particular for facades, improving the thermal comfort inside and around the building. The tree facades could become a new approach for designers of an aspect of architecture, both aesthetic and microclimatic, so far unexplored.

The man-made landscape is not just a manifestation of 'good' things that humans can produce: it is increasingly linked to physical and urban environmental deterioration and more, with settlements and communities experiencing social unease, pollution and inequality. It has been repeated several times in this presentation how the Anthropocene is leading to increasing use of resources, with profound and irreversible impacts on natural ecosystems. Health (also concerning Indoor Air Quality), security and sustainability are the paths that should guide social and technological development and innovation. Therefore, the potential of the combined use of 'grey' and 'green' solutions becomes important, to carbon capture and storage in the built heritage regeneration intervention, for the objective of halving carbon emissions by 2030 and being carbon-neutral by 2050, as established by European policies. This is the sense of the activities started by the working group at 'Sapienza', the University of Rome within the research PRIN 'Tech Strart' and the University research Climate-Pandemic-Proof Design. They were carried out through an application, on an experimental basis in a public housing estate in Rome, where 'green' (green infrastructures) and 'grey' solutions (materials with low embodied carbon and CO_2 absorption capacity) were developed synergically, systematically evaluating the impact in terms of reduction of climate-changing emissions compared to the current condition.

The subject of the ecological transition is also dealt with an environmental design that has taken a central role in political strategies and design considerations on urban regeneration and energetic and technological requalification. The improvement of environmental performances of the cities and the buildings aims for two important results: a better quality of life and places, following new socio-economic and aesthetic-cultural criteria, and a balanced relation between the built and natural environment, with their energetic and ecosystem advantages. Therefore, it is impossible not to consider the conditions of bioclimatic architecture, thanks to which technical solutions can be developed and adopted to rationalise the relationship between home and local climate, maximising favourable conditions, such as sunlight or ventilation, and minimising negative ones, such as humidity and frost. Considering that a sustainable approach to the architecture project cannot be separated from the consideration of the production sector present in the context of implementation, it is clear the importance of using wood species coming from a short supply chain. This necessarily entails many assessments on the feasibility of building solutions using wood as the most external layer in wall stratigraphy of ventilated perimeter walls. Italian forest areas, accounting for about 40% of the territory, are a source requiring sustainable management plans, aiming at the protection of biodiversity, with timber for the building industry sourced as much as possible from indigenous wood species, exploiting the opportunities offered by the forest bio-economy.

On the subjects revolving around the idea of landscape, the ecological transformation of urbanised water landscapes is quite important, starting from the idea that these places, in particular river deltas, are an insoluble twine of nature and culture, full of priceless biological and heritage assets. An analysis of these landscapes is reported by setting the interpretation of the methods through which the territory project deals with the environment through three categories having at their core the human material well-being, the untouched nature, and the search for a non-confrontational but mutually enhancing integration. The river landscape is constantly subjected to the growing instability of river ecosystems and the danger of flooding. These elements require risk management systems on a territorial scale, capable of handling territory protection, environmental improvement and biodiversity management, through models linked to the river ecosystem without imposing on it through rigid and constricting infrastructures. Taking the Po river basin as a reference and starting from the analysis of the potential of Ecological Landscape Design and Nature-based Solutions, we report some theoretical premises to create planning and design strategies on a large scale, without neglecting the ecological and ecosystem issues of river landscapes. Natural Parks too should be considered a precious resource for social and economic development, therefore, they need consideration, regeneration, and enhancement. These assumptions are the base of the proposition for experimentation in the Vulture Regional Natural Park (Basilicata, Italy). It aims to enhance the community identity and the territory's needs, keeping unaltered the aims of public administration together with the community. The project aims to be a pilot case, a 'rural workshop' that brings to life the inland economy, culture and innovation in a sustainable way.

Another improvement of the 'greenery' subject is provided by the Urban Environmental Design and, in particular, the study of connective paths, starting from Cadorna station to reach the Triennale in Milan. The study implements measures envisaged in the Master Plan destined for environmental, cultural and social regeneration of the Cadorna area, consistent with the European commitment to address climate and environmental issues concerning a competitive and resource-efficient economy. On the one hand, the urban systems play a role in the production of negative and climate-changing externalities, on the other, however, they are a privileged context for experimentation and innovation of virtuous practices of mitigation and adjustment of the impacts they generate. The urban environment is, then, a special scenario where we can analyse and observe the needs and desires of contemporary society. The implementation of 'nature-based' highly technological solutions provides for the investigation of technical aspects of plants as design materials, in terms of performance, durability and maintainability, and gives the possibility of identifying the plant species that can best perform shading and evapotranspiration, according to the specific climatic characteristics of the planting site. Through an analysis of quantitative data, it could improve the environmental, economic, and social sustainability of any environmental regeneration project.

These are the subjects collected in this volume, essays and research that, although not exhaustive, can fuel the international debate and give researchers a way to tackle the contemporary climatic, environmental and health challenges by, on the one hand, implementing 'virtuous connections' among the different stakeholders of the building process and, on the other, identifying the innovation drivers useful to spread the culture of social, economic and environmental sustainability that could favour, through conscious products and processes, the much desired digital and ecological transitions.

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MULTIDISCIPLINARY APPROACHES TO LANDSCAPE DESIGN

Chiara Catalano, Mariagrazia Leonardi

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ESSAYS & VIEWPOINT

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ABSTRACT
The European strategy to meet the sustainable development objectives which were put in place by the European Green Deal and the 'European Taxonomy' has created a need for the greening of our cities, intending to improve equity in terms of access, distribution, and the quality of green areas, as well as the promotion of human well-being and social justice, while also including species other than humans. The implementation of Nature-based Solutions, however, such as Blue and Green Infrastructure, can only be accomplished through the adoption of multidisciplinary approaches. It is, therefore, imperative that future landscapers are equipped with the ability to relate to and collaborate with other specialists and colleagues from other disciplines. With this objective, this paper presents two research activities which investigate two different teaching methodologies, within both public and private green spaces: the Ecological Driven Design (EDD) and the Green Experience Laboratory (GE-Lab).

KEYWORDS
landscape architecture, urban biodiversity, habitat, ecological landscape design, design for nature

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The recent European Strategy to meet the UN's Sustainable Development Goals (UN, 2015), along with the publication of the European Green Deal (European Commission, 2019) and the recent European Taxonomy for Sustainable Activities (EU Technical Expert Group on Sustainable Finance, 2020; Lucarelli et alii, 2020) has led to the greening of cities, to improve equity in terms of access, distribution, and the quality of green areas, as well as the promotion of human well-being and social justice, while also including species other than humans. However, the implementation of so-called Nature-based Solutions (Eggermont et alii, 2015) such as Blue and Green Infrastructure, can only be accomplished through the adoption of multidisciplinary approaches, which expand upon the available knowledge surrounding the ecology of a given urban green space (Lepczyk et alii, 2017). This allows practitioners to better support and manage urban biodiversity (Aronson et alii, 2017) and to develop a more widespread acceptance of the peculiar aesthetics of urban wilderness (Ignatieva, 2017; Nassauer, 1995).

The consideration of ecological principles, i.e., the natural processes and the relationships among them, is fundamental to the implementation of sustainable landscape design. An awareness of this has given rise to the Ecological Landscape Design movement, which is a holistic design approach based on landscape ecology, to maintain landscape integrity, while also strengthening the natural and cultural spirit of the area (Çelik, 2013; Makhzoumi, 2000; Makhzoumi and Pungetti, 1999).

This paper presents two multidisciplinary teaching methodologies and case studies, related to both public and private green spaces, with both a group of students enrolled in the Natural Resources Sciences Bachelor's degree program at the Zurich University of Applied Sciences (ZHAW) and another enrolled in the Territory, Environment and Landscape Protection Master's degree program at the University of Catania. The two methodologies investigated were the Ecological Driven Design (EDD) method and the Green Experience Laboratory (GE-Lab) method. The aim in both cases was to provide future landscapers with transferable skills that allow them to work in multidisciplinary groups, by providing them with a replicable method for approaching design projects in an ecosystemic way.

Ecological Driven Design (EDD) for natural and environmental sciences students | Across Europe, the recent collaboration between landscapers, designers and biologists has resulted in the development of methods such as Animal Aided Design – AAD (Weisser and Hauck, 2017) and other experimental approaches based on multidisciplinary collaborations (Whitelaw, Hwang and Le Roux, 2021), all of which have the aim of creating inclusive cities, which are also designed with wildlife in mind (Apfelbeck et alii, 2020), i.e., urban habitats where biodiversity can be promoted by stimulating citizens' involvement (Garrard et alii, 2017). Similarly, a European project called Ecolopes (Canepa et alii, 2022) and an international Switzerland-France collaboration titled DeMo (Catalano et alii, 2021), aimed to develop a methodology for creating inclusive and regenerative building envelopes from an ecosystem perspective, by em-

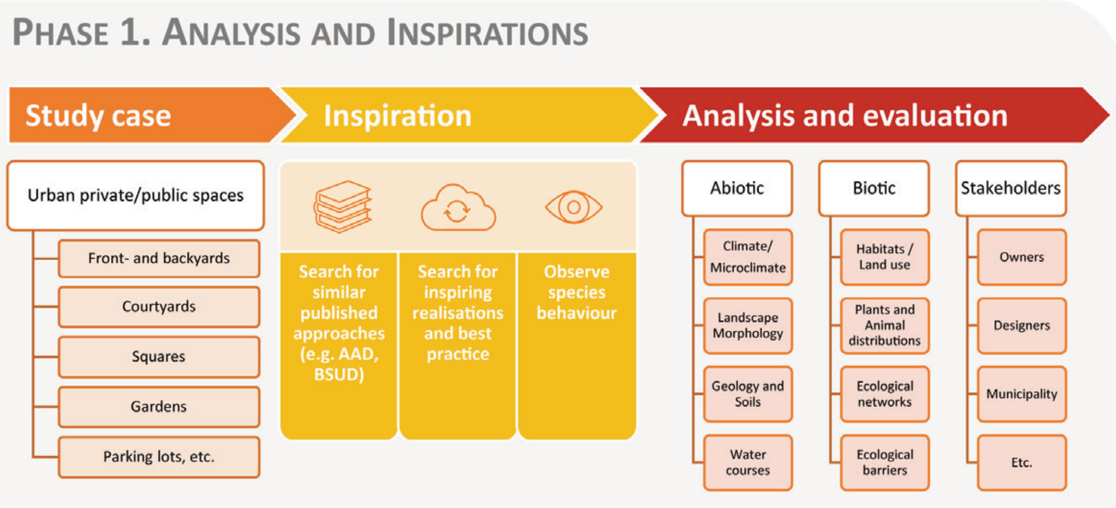


Fig. 1 | Methodological diagram, phase 1 of the EDD method (credit: C. Catalano, 2022).

ploying a multidisciplinary, computational and reproducible design approach. This line of research and application abandons the classic anthropocentric design vision, which aims to satisfy the comfort and well-being of humans, in favour of a multi-species approach.

In Switzerland, the federal biodiversity strategy explicitly addresses urban areas and considers settlements to be an essential factor in the preservation of the species deprived of their natural habitat (FOEN, 2012). The EDD, which is investigated in this study, fits the abovementioned international context and adheres to the guidelines set by the Swiss national strategy. It aims to provide natural sciences students with a reproducible design method, which has the goal of increasing the biodiversity of certain urban habitats, such as private gardens and courtyards. The hypothesis behind this methodology is that small but connected interventions which are made at an urban scale can be implemented at a territorial scale to support the urban ecological network, as it does with green roofs and walls (Braaker et alii, 2014). The EDD consists of three main phases[1]: 1) spatial analysis, ecological assessment of the site and stakeholder analysis; 2) the selection of animal species guiding the design intervention; 3) the planning and design of interventions. In addition to visual materials, students are asked to compose a text related to the project, which is structured like a scientific text, i.e., including an introduction, materials and methods, results and discussion, and conclusion sections.

Step 1: Analysis and Inspirations | The analytical phase is preceded by a literature review, which is accomplished by conducting a keyword search on Google Scholar and Web of Science. The literature which is gathered here will ultimately be utilized in the introduction of the final paper (Fig. 1). By consulting 'peer-reviewed' publications, students should be able to contextualize the objectives of the project in a manner consistent with the solutions and strategies in support of biodiversity (such as nature-based solutions, or biodiversity action plans) implemented in Switzerland and other European countries. They also search for projects that are similar to their case study, and which shall inspire the design of the interventions. These best practices contribute to the content of an 'inspiration journal', which the students prepare along with their final paper.

Following their literature review, the students complete a spatial analysis, which focuses on the analysis of the abiotic (e.g., climate, geology) and biotic (e.g., habitat, data on species presence) components, to identify ecological corridors and barriers. In particular, the ecological assessment of the site is made according to the checklist developed by the urban ecologist S. Ineichen[2], which allows for the qualitative evaluation of both the entire area of intervention and the individual structures characterizing it. The parameters used for the overall evaluation are the degree of imperviousness, ecological connectivity, and the presence of undisturbed areas. In the case of small structures, the parameters used are the floristic diversity, the origin of the plant species

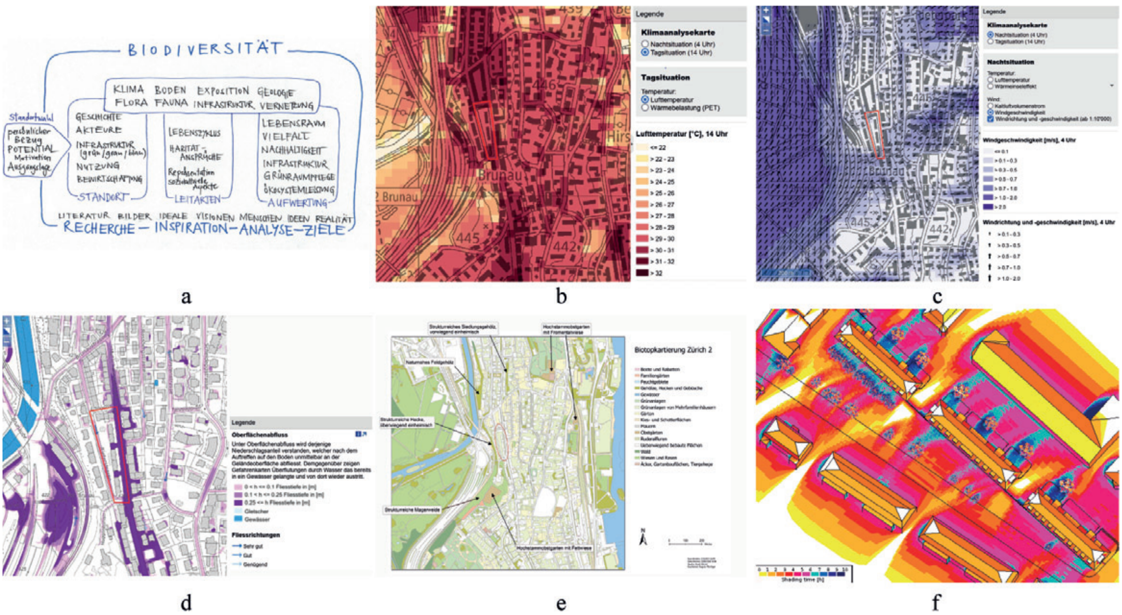
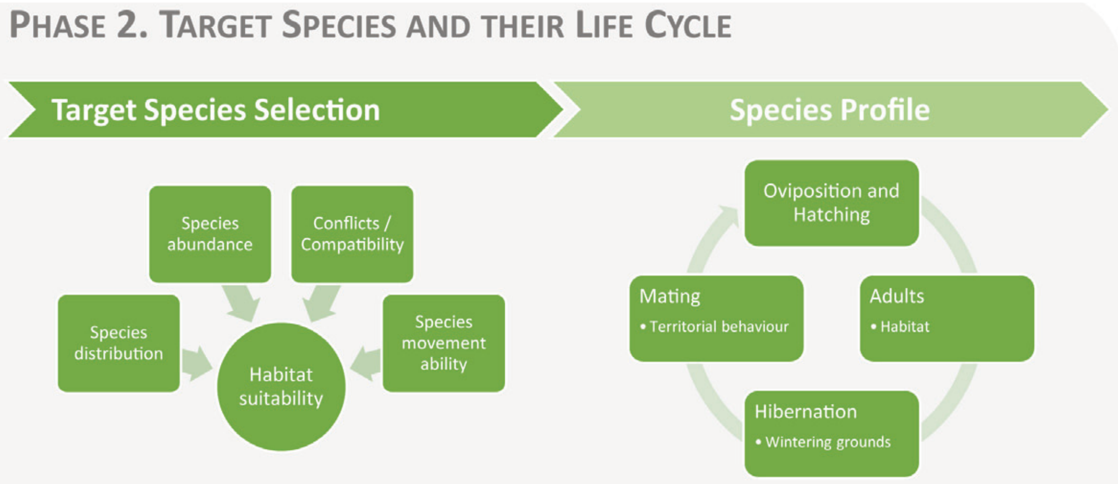


Fig. 2 | The study case; a) customized diagram of the EDD method; b) thematic maps of temperature, c) wind intensity, d) surface runoff and e) urban biotopes; and f) shadow analysis (20th of June) of the area of intervention (credit: R. Flückiger, 2021).



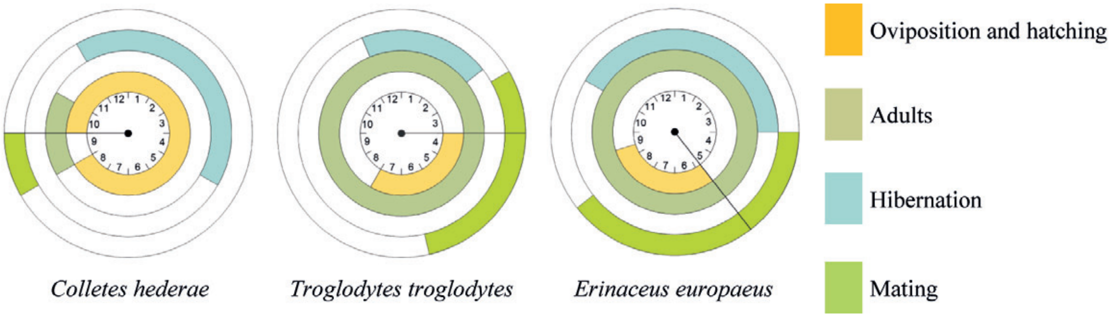


Fig. 3 | Methodological diagram, phase 2 of the EDD method (credit: C. Catalano, 2022).

Fig. 4 | One-year life cycle of the ivy collet 'Colletes hederae', the common wren 'Troglodytes troglodytes' and the common hedgehog 'Erinaceus europaeus' (credit: R. Flückiger, 2021).

(presence of native or exotic plants, in any case consistent with the place), the age of the individuals, and the type of maintenance (sustainable or not). Students are asked to synthesize the information they have collected, customize their proposed method (EDD) to make it their own (Fig. 2a), and present everything in an easy-to-understand, visual style. The spatial analysis at both the territorial and urban scale is carried out on GIS-browsers at different levels of in-depth analysis (municipality, canton, federation), and represented through thematic maps (Fig. 2b-e). On a smaller scale (varying according to the object of study) a shadow analysis is carried out so that specific interventions can be optimally positioned, that is, in relation to the needs of the selected plant species (Fig. 2f).

Step 2: Animal species selection and their Life Cycle | A crucial part of this method is the selection of some animal species (characteristic of certain surrounding habitats), which is based on the spatial analysis of the site and is, therefore, site-specific (Fig. 3). The specific needs which are identified for species throughout their life cycle (Fig. 4) are based on reliable sources (federal wildlife monitoring sites, lessons from other courses) and summarized in so-called 'species profiles', according to the Animal Aided Design method (Weisser and Hauck, 2017). Students are allowed to choose a maximum of three species, which are limited to those included in the complementary modules in their study program among amphibians, reptiles, birds, beetles, bees and bats. An exception is the common (or European) hedgehog 'Erinaceus europaeus', which may be selected because it is already included in several urban biodiversity conservation programs in Switzerland.

The students must define and explain the criteria for choosing species individually, but among the conditions set, the selected species must already be present in the study area based on federal distribution maps (provided by the Swiss Wildlife Protection and Information Centres) or observations recorded by the Global Information Biodiversity Facility (GIBF, an international network aimed at providing free data on all types of life globally). The final choice of the three species is influenced by the stakeholders involved and the conflicts/compatibility among species (including humans).

Step 3: Conceptualization and Design | The design of the individual interventions to support the local biodiversity is the result of the ecological analysis, stakeholder involvement, and the needs of the selected animal species (Fig. 5). In the case study which was utilized by the student R. Flückiger[3] (Fig. 6), for example, the choice of the

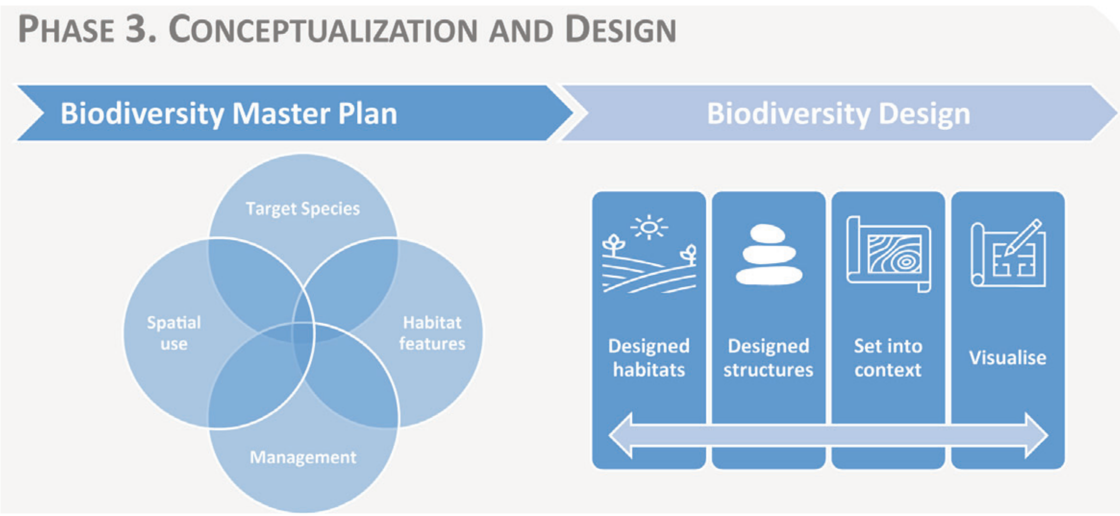


Fig. 5 | Methodological diagram, phase 3 of the EDD method (credit: C. Catalano, 2022).

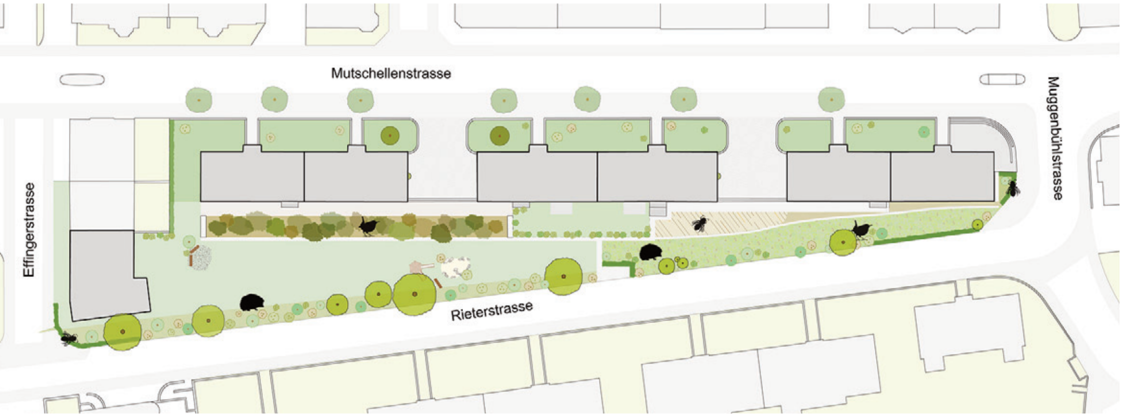


Fig. 6 | Contextualization of the interventions at the site (credit: R. Flückiger, 2021).

ivy bee (also suggested by the presence of several ivy hedges on site which represent the main source of nectar and pollen for this species), brings as a consequence the need to create one or more sunny ruderal areas with a sandy substrate and small annual plants necessary for nesting. Conversely, in targeted interventions which support wren instead, the cherry laurel hedge should be replaced by a mixed one with dogwood, barberry and blackthorn. In the same way, the common hedgehog is linked to structurally rich and dense margin vegetation, but without barriers. In this specific case, the area adjacent to the road (Rieterstrasse in Zurich) should therefore be planted with a herbaceous border supplemented with native woody plants such as dogwood, rowan and wild roses. In addition, the dead leaves and pruning piles, which must therefore be left on site, would serve as a shelter for hedgehogs, a foraging site for the wren which feeds on insects, caterpillars, worms and small spiders, and also a source of nesting material.

Green Experience Laboratory (GE-Lab) applied research and approach to the urban landscape for landscape agronomists: design experiences in the historic centre | The Laboratory has two integrated modules: Landscape Design and Redevelopment and Restoration of Degraded Areas to Green. The work focused on public spaces, and on how to deal with a multidisciplinary approach to an ecological transition in a strongly consolidated and historicized urban environment, while following the indications of the Italian National Recovery and Resilience Plan (PNRR). The work was conducted with the Landscape Architecture discipline and the agricultural Horticulture and Floriculture disciplines, and consists of three main phases: 1) spatial analysis, with the definition of guidelines for the synchronic and diachronic analysis of places and the study of existing landscape and urban planning; 2) synthesis and definition of judgments on critical issues and potential; 3) the planning and design of green redevelopment interventions of the places to be converted into public spaces. In addition to the visual materials, students are asked to create a multimedia presentation related to the project, structured according to an introduction, materials and methods, results and discussion, and a conclusion section.

The case study which was used revolved around the historic centre of the city of Catania, Sicily. If history represents the sense of belonging to something that has existed since before us, in forgotten but historicized places, the designer – through the experience of being in those spaces, where the present is interwoven with the past, and the signs of history are interspersed with the most recent contemporaneity – can try to transfer his or her feelings to the citizens who live in those places (Leonardi, 2021). The work in this case focuses on the ability to make citizens reflect on where they live, thus restoring lost, fragmented, or forgotten places within their consciousnesses.

The design research of recent years (Pica Ciamarra, 2018) has attempted to demonstrate how space, remarkably versatile with respect to meeting the varying needs of its inhabitants, can be considered essentially a place of relationships. The designer must therefore be able to trigger processes of participation, together with associations or dedicated bodies, which inform citizens and administrations of the potential of public spaces, local cultural and landscape heritage, and a sense of identity. From this perspective, with the help of ICT, the city could become increasingly smarter, and find an innovative new way to communicate its artistic, cultural and landscape heritage. It could also become increasingly greener, by reintegrating architecture and nature in the redevelopment of abandoned landscapes.

In compliance with the principles of the Charter of Public Space in Rome (Biennale of Public Space, 2013) and the subsequent proposals promoted by INU – National Institute of Urban Planning and UN-Habitat (2016) – United Nations Program for Human Settlements in the creation of a Global Toolkit on Public Space, in particular, the course worked on the green aspects of the redevelopment of the open spaces around the abandoned Vittorio Emanuele Hospital Complex in the 'Quartiere Antico Corso' in the historic centre of Catania. The Hospital Complex is located adjacent to the former Benedictine Monastery of San Nicolò La Rena, which was redeveloped by the architect Giancarlo De Carlo and is a UNESCO Heritage site. It extends over the area of the former Benedictine Flora. It will be reconfigured to become the third green lung of the historic urban centre, after Villa Bellini and Villa Pacini.

According to the forecasts made by the Detail Study L.R. 13/2015, the area is subject to urban restructuring, with the conversion of the Ancient San Marco Pavilion into the Museum of Etna and Sicilian Identity, and the demolition of some particularly degraded hospital pavilions, so that the currently existing garden can be expanded, and an urban park can be created for the neighbourhood. From these premises comes the action research aimed at enhancing biodiversity and recovering a sense of memory of the places. After a careful analysis of the area which, in addition to hosting the remains of the 'Ex Flora Benedectina', is strongly characterized by the permanence of

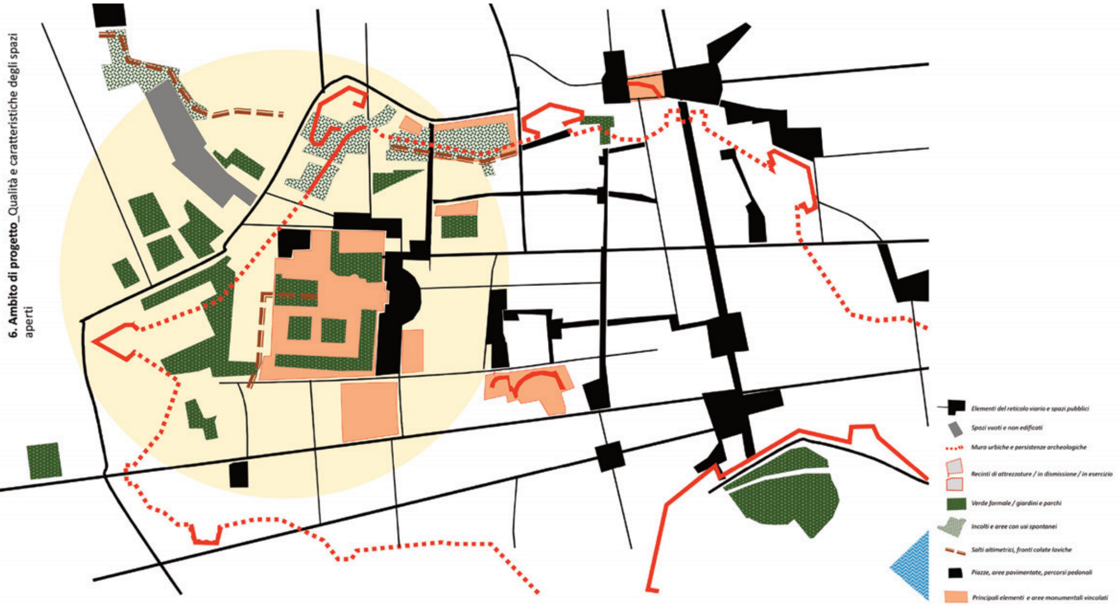


Fig. 7 | 'Quartiere Antico Corso' in the historic centre of Catania: the system of the walls of Charles V, the archaeological remains, the remains of the lava flow that swept over Catania in 1669, the green system, the Baroque monumentality UNESCO Heritage of the urban reconstruction after the 1693 earthquake (credit: M. Leonardi, 2021).

the historic walls of Charles V that surrounded the city of Catania, and by the persistence of the lava flow from 1669 still resurfacing, it was decided to focus on themes that aim to enhance the history of the area, and to select Nature-based Solutions that promote biodiversity in urban areas by carefully choosing which plant species are introduced. The phases of the action-research are as follows.

Step 1: Analysis | The analytical phase is preceded by bibliographic and cartographic research at libraries and in historical archives. The above material and landscape and urban planning existing documents are given to the students. Inspections are then organized on the project area, during which students are supported by a team of teachers with multidisciplinary skills able to guide them through the recognition of existing fauna and flora species, and the organization and composition of the spaces. In collaboration with the disciplines of Ecology and Landscape Analysis, students learn how to use a GIS Browser able to analyze and define the state of affairs with thematic maps of the different landscape components. Through the help of CAD software, they learn how to reconstruct the state of the places, starting from the existing cartography. Bodies or associations dedicated to urban participatory enhancement are also involved during the inspections, to represent the needs of local stakeholders.

Projects and realizations applied to similar case studies that can be a support for the work are also presented by teachers or experts, and students are invited to deepen their knowledge of those they perceive to be closer to their ideas for transforming the places. The ecological assessment of the site is carried out in collaboration with the teacher of the of Landscape Ecology course, a module integrated with Landscape Analysis, within the Ecology and Landscape Analysis course.

Step 2: Synthesis | After having conducted, with the help of specialists and through the existing thematic literature, an in-depth analysis of the existing plant and faunal species, and the botanical species present in the Benedictine Flora (Pagnano, 1984), and after having focused on the study of the historical plans of the city of Catania and in particular of the 'Quartiere Antico Corso' and the Benedictine Flora published in the literature (Amico 1757-60; Leanti, 1761; Hittorff and Zanth, 1835; Dato, 1983; Pagnano, 1984; Cusa Gentile, 1994; Atripaldi and Costa, 2008), at libraries, or in historical archives[4], the students are ready to synthesize what they have learned. This is accomplished by making judgments on the critical issues and the potential of the places with a SWOT analysis. This analysis presents hypothetical thematic gardens that in some way can reconstitute the spirit of the place, even though it has a contemporary look, and even though the public space will be reconfigured to provide its citizens with a new urban park. The thematic gardens which are designed also assume an educational and didactic function for visitors, as they are assisted by ICT technologies

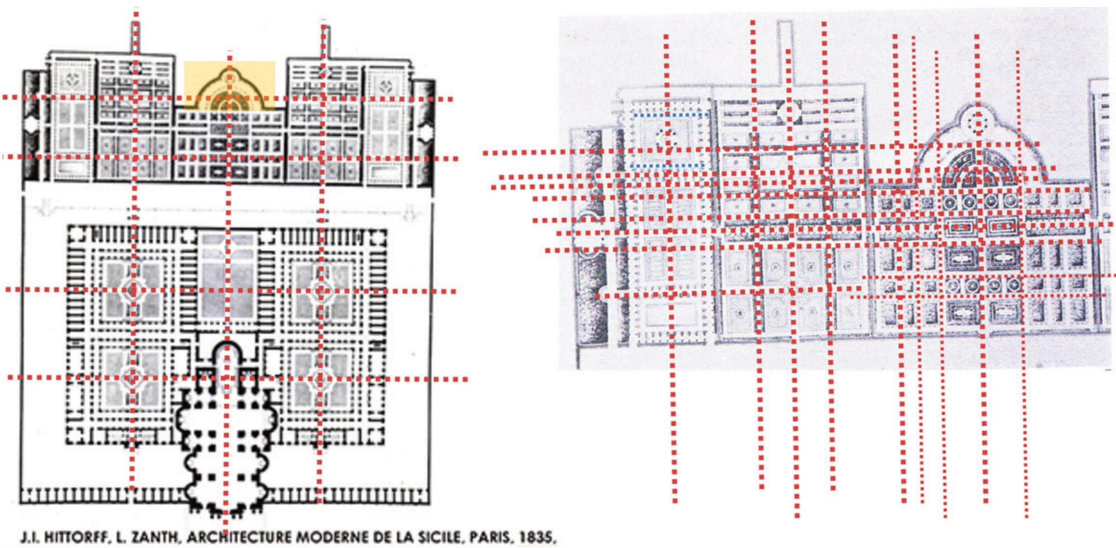


Fig. 8 | The Benedictine Monastery of San Nicolò La Rena and its Flora: the system of axes (source: Hittorff and Zanth, 1835).

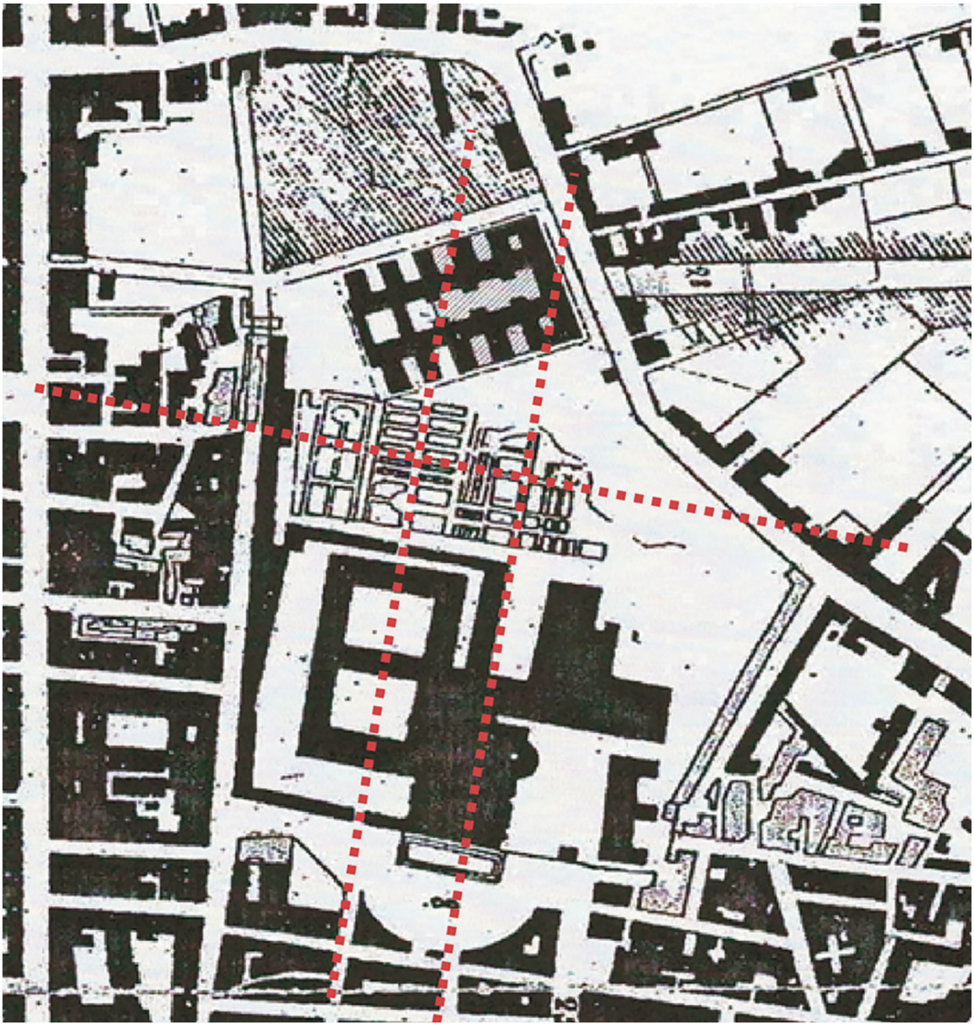


Fig. 9 | The Benedictine Monastery of San Nicolò La Rena, its Flora and the San Marco Hospital Pavilion: Master Plan of Renovation and Expansion of the City of Catania proposed by Eng. Gentile 'Ufficio d'Arte Comunale', year MDCCCLXXXVII and the system of axes (source: Cusa Gentile, 1994).

that in some way reconstruct the history of the places, describe the botanical species present, and the animal biodiversity that follows (Figg. 7-11). A fundamental aspect of the multidisciplinary comparison is identifying which plant species can be used to help recover the degraded spaces, based on the spatial analysis of the site and the specific potential of the context. From this choice, a spontaneous faunal repopulation follows that can still be compatible with the public use of the spaces. Students must define and explain the criteria for choosing species with special cards and schedules.

Step 3: Design | The result of the analysis and synthesis phases is the planning and design of the green redevelopment of the places to be converted into public spaces. The project is addressed and controlled in its multiscale components from the initial masterplan up to the definition of the construction details of the urban elements. For example, Figures 10 and 11 represent a part of the project developed by the students A. Iozzia, and G. Stracquadanio. In the spirit of recreating a park in harmony with its historical context, where the usability of the inhabitants and tourists is always made possible, and taking into account the accessibility conditions defined by studying the results of the Biennale of Public Space and UnHabitat, and by introducing different recreational, environmental and cultural functions, the area, also connected with the Benedictine Monastery through the Battaglia bridge, is designed with overlapping layers, which logically relate to one another.

The first layer represents the partition of the pathways, based on a diachronic analysis of the axes of the Benedictine Flora (axes of the Monastery, the Battaglia Bridge and the historic Garden of the Benedictine Flora: main project pathways parallel to the Novice Garden). The second consists of a cycle and pedestrian pathway which encloses a multifunctional surface. The third layer is contained within this pathway and is based on circular modules. The park is characterized by several discrete areas: recreation (cycle-pedestrian track, sports, playgrounds), refreshment (equipped with rest ar-

Fig. 10 | The design of the green system in Catania, Project 'The gardens of OVE – Vittorio Emanuele Hospital' in 'Quartiere Antico Corso' (credit: A. Iozzia and G. Stracquadanio, 2021).

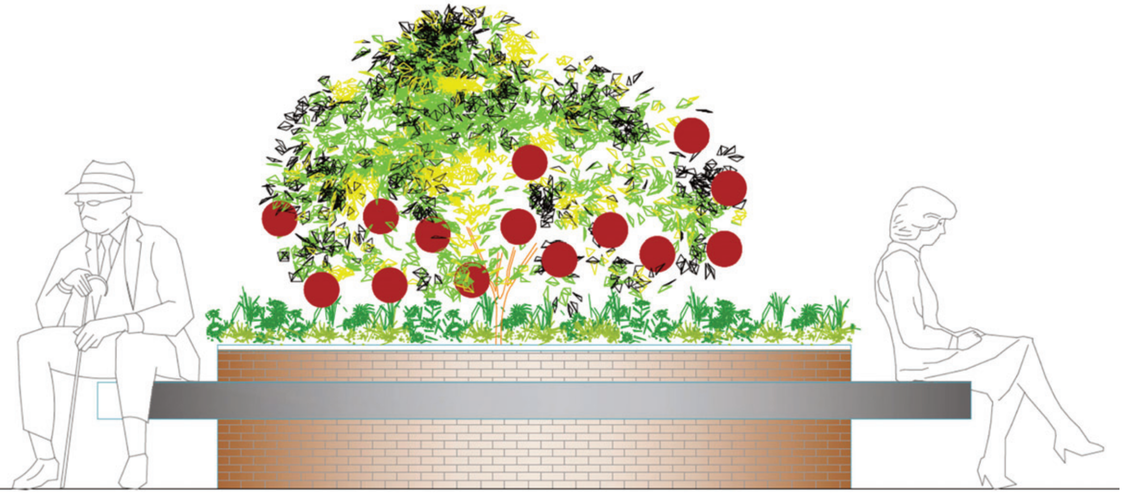


Fig. 11 | Detail of a flowerbed-bench ('Punica granatum') in Catania, Project 'The gardens of OVE – Vittorio Emanuele Hospital' in 'Quartiere Antico Corso' (credit: A. Iozzia and G. Stracquadanio, 2021).

eas), educational (info-point, green areas), and thematic gardens (Gardens of perception, Rock Garden, Evergreen Garden). The choice of the botanical species of the project was made based on the climatic and soil conditions (in which the students operated), and the maintainability, considering the limited public financial resources as well as the ability of the selected species to contribute to animal biodiversity.

Concluding remarks | The case studies shown here respond to the need to direct students towards the ecological transition that is taking place on a European scale, which supports biological diversity in the urban environment. Simultaneously, this demonstrates how the dialogue between different professionals and their related skill sets is not only feasible but also necessary to the success of the different design phases. The common purpose of the workshops is in fact to create spaces that increase biodiversity and social well-being (Un-Habitat, 2022). It, therefore, seems clear that it is necessary to further integrate the curricula of the natural sciences and landscape architecture so that new professionals can be trained to work in multidisciplinary groups. This would therefore increase the spectrum of skills in the field of landscape architecture, by starting from an ecological understanding of the landscape. The studies and applied methodological research start from the common idea of a multidisciplinary approach to landscape design, although they differ in the choice of existing case studies. The EDD method has been applied to green areas adjacent to condominiums or private neighbourhoods, while the GE-Lab focuses on the redevelopment of pieces of land and public spaces in highly historicized environments.

In summary, in the case of the EDD, the stakeholders are both the animal and plant species considered through the analysis of the vital critical needs of the animal species, as well as private individuals, municipalities and other professional figures (for example architects and landscape architects). All the interventions are related to each other in an ecosystem vision that generates benefits and opportunities both for users and for local flora and fauna, converging with the above-mentioned approaches on a European scale.

Among the limitations identified, there was the difficulty to incorporate the ecological needs of the animal species and habitats into the landscape project along with the expectations of the owners, which were not necessarily focused on protecting biodiversity, and who were possibly afraid of the costs that such interventions could cause (nature-city conflict); the difficulty of finding ecological data that is accessible and available at the municipal level in high resolution; the difficulty for students to translate ecological knowledge and data in a conceptual, spatial and functional way. These limitations and criticalities are consistent with the results obtained in the survey addressed to students and professionals in the field of architecture and construction published by Catalano and Balducci (2022).

On a theoretical level, the various methodological phases have been described in detail to make them applicable in other contexts and similar case studies. The study cases presented here can be implemented at the same time, improving through previous experiences and new objectives in an iterative and non-linear feedback-loop or 'design thinking' system. The GE-Lab laboratory experience has been applied to abandoned open spaces in highly consolidated historic centres for their conversion into public places and the enhancement of biodiversity. We tried to follow a model of approach to the project that, along with its multidisciplinary component, can be replicable. Also, in this case, the interventions are managed with an ecosystem vision that generates benefits and opportunities for both the users and the local flora and fauna. Among the critical issues and limitations encountered, communicating with public bodies and stakeholders also led to some difficulty. In this regard, collaboration with urban sociologists should certainly be encouraged. The methodology attempts to apply the principles derived from the international UnHabitat experiments, reconciling them with the PNRR and the ideologies supported by Pica Ciamarra, and it tries to emphasize their multidisciplinary contributions. The work, which has been verified in small urban areas, should, however, be experimented with at both the urban level, with the creation of ecological corridors connecting parks and public gardens, and at the territorial level.

The results of these pilot projects suggest the possibility of applying the methods in other contexts in a synergistic way. The Mediterranean environment lends itself as a biodiversity hotspot, both from the point of view of multi-layered cultural landscapes and from the ecological and naturalistic point of view. This is consistent with the strategy envisaged in the Italian National Recovery and Resilience Plan (PNRR).

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Notes

1) For more information see: Catalano, C., Jüstrich, S. and Baumann, N. (2021), *Praxisauftrag UÖ2 2021 – Vom Lebensraum zum Ökosystem – Design [Practical assignment UÖ2 2021 – From habitat to ecosystem design]*, Students' class material of the Course 'Urban Ecosystem – Fundamentals 2', BSc degree in Natural Resource Sciences, Zurich University of Applied Science. [Online] Available at: moodle.zhaw.ch/mod/resource/view.php?id=155683 [Accessed 17 June 2022].

2) For more information see: Ineichen, S. (2020), *Naturnahe Grünräume- eine Checkliste für Grünflächen, Wohnumfeld, Garten und Parks [Natural green spaces – A checklist for green spaces, living environments, gardens and parks]*, Students' class material of the Course 'Urban Ecosystem – Fundamentals 2', BSc degree in Natural Resource Sciences, Zurich University of Applied Science. [Online] Available at: moodle.zhaw.ch/pluginfile.php/202680/mod_folder/content/0/U%C3%962_L_2020_Naturnahe-Gr%C3%BCnr%C3%A4ume-eine-Checkliste_Ineichen.pdf?forcedownload=1 [Accessed 17 June 2022].

3) For more information see: Flückiger, R. (2021), *Lebendige Inseln in der Stadtlandschaft – Aufwertungsmassnahmen für die Siedlung Mutschellenstrasse | Living islands in the urban landscape – Upgrading measures for the Mutschellenstrasse settlement*, unpublished work, Course 'Urban Ecosystem – Fundamentals 2', BSc Degree in Natural Resource Sciences, Zurich University of Applied Science.

4) For more information see: Orlando, F. (1761), *Veduta della città di Catania* (source: Archivio Storico del Museo della Fabbrica del Monastero dei Benedettini, Catania); Ittar, S. (1832), *Topographic plan of the city of Catania, Paris ca., engraving on copper, cm 78,5×53,4* (source: Biblioteche Riunite Civica e Ursino Recupero di Catania).

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Fig. 12 | 'Chamaenerion angustifolium' (L.) Scop. and visiting bumblebee, biodiverse green roof of the Europaallee 21, construction area C, Zurich (credit: C. Catalano, 2014).

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ABSTRACT
Over the last half-century, society has faced the scene of its future self-destruction and the unique condition of being aware of it, witnessing the alarms and warnings for our well-being and lifestyles. The anthropic landscape remains in a state of physical and environmental degradation, with settlements and communities experiencing social distress, pollution and inequality. Physical space, and its formal and social outcomes, are the product of human activity on the environment, adapted and manipulated to build settlements according to unsustainable lifestyles. Before the second industrialisation, human settlements were created by adapting human needs to the characteristics of the natural environment without compromising resources. Today, such ability to respectfully inhabit places is lost. The rate of technological innovation is weakened by consumerist logic, rather than strengthened in the direction of well-being and impact, and the construction industry is not immune to this trend. Health, safety and sustainability are the tracks that should guide development and innovation, both social and technological, the paper aims to rediscover and update these concepts within the construction process, to pursue a new balance between the built and natural environment.

KEYWORDS
living, environment, sustainable architecture, indoor air quality, technology

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The issue of sustainability is unavoidable in the discussion on the development models that contemporary society, on the brink of environmental collapse (Morton, 2019), should aspire to. Under scrutiny, individual habits, political strategies, and industrial productions. Everything contributes to the consolidation of counterproductive development prospects, seemingly innovative on the socio-economic level, but profoundly dangerous on climate and environment. The effect is increasingly evident in extreme climatic phenomena that, with the help of unrestrained anthropisation (Gould and Vrba, 2008), multiply the frequency of environmental disasters worldwide. To build a sustainable consciousness, the media play a central role, increasing community awareness of the risks to which the planet and people are subjected daily.

Pollution and toxic emissions and land consumption on a global scale (Stiglitz, 2006) are the ones for which many measures and strategies have been put forward. In early 2000s, also the world of design was questioning (Manzini 1997; Vezzoli and Manzini, 2007) the challenges of sustainability, which could only be achieved through a progressive dematerialisation of processes, products and services, which required a ‘leapfrog’ of all the actors involved. Today, sustainable acceleration on a political, regulatory and design level, pursue environmental performance and risk prevention, recognising the economic, productive, and ecological results. Indeed, contemporary culture, strongly conditioned by capitalist demands for greater technical and economic availability and independence from natural resources, continues to erode and weaken the environment without fully satisfying the needs for urban quality and well-being for its inhabitants (Bragança et alii, 2010). From this complexity, new challenges emerge to ensure adequate well-being and quality of living, technological and social innovation and climate justice.

Sustainability scenario | After the many national and supranational strategies focused on sustainable development, it is necessary to reflect on the progress made and how to shape future measures, taking into account negative trends such as the growing demand for non-renewable resources and energy for industry, buildings and transport. While the objectives of sustainable development to contain the climate crisis are clear, the path to follow at the political level remains vague, while the financial market mobilises with investment initiatives to support the industrial sector to mitigate – sometimes only apparently – its ecological footprint. The paradox brings to the same side of the fence the same actors involved in the worsening climate crisis, who espouse the concept of sustainability for marketing purposes, without implementing or monitoring the impact of erosive production models. CO_2 emissions are increasing (IEA, 2022) and at every international summit, from the Rio Conference (UN, 1992) to the present day, increasingly ambitious goals are announced without having the tools to put them into practice, far from a real turnaround, at least on a global scale (Faloppa, 2016).

Beyond the theoretical and conceptual level, the complexity of sustainability lies in the difficult management of the multiple factors that condition all the productive sec-

Fig. 1 | Indoor Air Quality: 5 Things you need to know (source: Panasonic Corporation of North America).

tors, material and immaterial, of design and services. On the other hand, innovation in design and technology allows us to see, in the field of architecture and construction, concrete prospects for containing the environmental impact and the well-being of individuals in terms of health, comfort and safety of occupants (ECA, 2003). The call for greater scientific rigour is to be welcomed, lest environmentalism evaporates into propaganda, rhetoric or conformism. Already, the report A New Climate for Peace (Rüttinger et alii, 2015) called for the recognition of climate change as one of the threats to the stability of states and society, towards an inevitable and irreparable environmental catastrophe that should be taken into account. The most recent European political strategies (European Commission, 2019) foresight scenarios of environmental, economic, social, and pandemic crises, towards a new sustainable balance that counteracts the wild and predatory use of non-renewable resources.

Based on these assumptions, the contribution presents some research reflections to understand the principles that animate sustainable architecture (Özdamar and Umaroğullari, 2018). That is, whether they are more health, ecology, social justice or economic oriented, implying a cultural transformation and a technical revolution on the social and design spheres and their mutual impact. The implications on production systems, instead, simplified the industrial process while complicating the net of interrelationships between the disciplinary sectors involved. Thus, the concept of 'global technology assessment' (or technology evaluation) of the environmental impact of innovations in sustainable architecture design, according to a multi-criteria and multi-stakeholder approach to monitor and evaluate the obstacles – institutional, financial, legislative – and the solutions to overcome them. The building sector resists the ecological transition of its traditional processes, failing to challenge them problematically more closely related to designers and companies rather than to the market that has already aligned itself to the new requirements. According to Campioli (2005), the issue of pollution produced by the construction industry is a social issue, as it affects the quality of life, people and the environment, with catastrophic effects on the ecosystem and the economy.

The urgency to rethink development processes is a primary goal for national and supranational agendas and for non-academic scholars working on the formulation of degrowth alternatives that are clearly at odds with the paradigms that characterise today's society: capitalism, technicism and globalisation (Latouche, 2013, 2014). The issue that closely concerns the world of architecture and construction is the mutual implications of technique and technology in the growth of the global market and economic wealth at the expense of the environment. The goal of finding compatibility between transformation and environment, artefact and nature, production needs and

Fig. 2 | Emissions of air pollutants continue to play an important role in a number of air quality issues, states the Environmental Protection Agency (EPA) that, in 2018, about 76 million tons of pollution were emitted into the atmosphere in the United States; these emissions mostly contribute to the formation of ozone and particles, the deposition of acids, and visibility impairment (source: Danrich Environmental Controls Ltd).

Fig. 3 | Plants demonstrate important aspects of natural air purification, humidification and filtration that occur without the use of energy (source: Nedlaw Living Walls Official, nedlawlivingwalls.com).

Fig. 4 | The targeted use of vertical green enclosures to take advantage of possible air quality improvement qualities provides such systems with peculiarities that no other type of building wall can boast (source: Nedlaw Living Walls Official, nedlawlivingwalls.com).

global security requirements, is the real challenge for sustainable and self-sufficient architecture. The contribution discusses the interrelation between the concept of eco-compatibility and healthiness underlying sustainable architecture, with particular reference to Indoor Air Quality (IAQ).

From sustainability to IAQ | The discourse on sustainable development is influenced by different schools of thought (Lanza, 2006) due to heterogeneous boundary conditions, although they agree on the necessary measures to be taken in the construction sector: the formulation of verification criteria for use by the planner to contain the waste of resources, harmful emissions and any activity that threatens the availability of non-renewable resources, the healthiness of the urban and built environment and the wellbeing of individuals (Fig. 1). The most widespread sustainability criteria are global, difficult to scale and therefore difficult to apply in the design process that is also confronted with socio-economic demands oriented towards environmental issues. This gap is bridged by two perspectives: the 'glocal' one on the one hand and the trans-disciplinary one on the other. It is customary to integrate studies from different and very distant disciplinary fields: energy conservation, bioclimatic architecture, indoor air, materials technology, economic compatibility of innovative plants or waste management. These disciplines are united by the objective of conscious design, a synthesis between the needs of production, the needs of contemporary society and the laws of nature, and pursue an experimental approach, no longer exclusively theoretical.

Sustainable materials and technologies are proposed through design expressions appropriate for the recovery of concepts such as healthiness (Fig. 2) and material place of the project, oriented towards traditional construction techniques to counterbalance the negative impact of the use of chemical and synthetic materials for building components, furniture or finishes. In the absence of adequate regulations, controls and product testing, these sometimes proved to be a potential source of indoor air pollution in homes, offices and public places. This phenomenon worsened in the 1970s, with the energy collapse linked to the Middle East crisis and the oil market. Lacking resources to power heating and cooling systems, energy containment was pursued through the hyper-insulation of buildings and the strict enforcement of Italian Law 373/76. The sealing of the rooms and the inevitable lack of adequate air exchange led to a rapid deterioration of IAQ, previously guaranteed by the uncontrolled and inevitable leakage from windows and doors that were not perfectly sealed. Paradoxically, the worsening

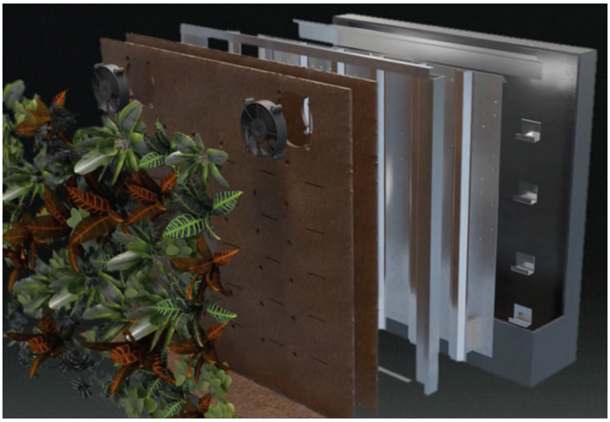


Fig. 5 | The ways in which plants affect air quality involve two factors: the natural humidification of the atmosphere and the biofiltration of pollutants (source: Nedlaw Living Walls Official, nedlawlivingwalls.com).

Fig. 6 | The use of vertical greenery as an air treatment system was adopted by a system called BioWall to emphasize its biofiltration characteristics. A few years later, in 2004, the same was patented in the U.S. under the name NEDLAW Living Wall. It consists of passing the air extracted from a given environment through the felt substrate of a plant wall: the cooperation between the physiological activity of the plants and the actions brought into play by the microorganisms present generates a passive purification of the air that will be ready to be re-injected into the same room. Harnessing the energy provided to them by the sun or by specific electric lamps, plants metabolize and mineralize organic or inorganic molecules in the atmosphere, while the action of bacteria helps eliminate both normal suspended dust and some pollutants such as formaldehyde, benzene, toluene, carbon monoxide, xylene, trichloroethylene, nitrogen oxides (source: Nedlaw Living Walls Official, nedlawlivingwalls.com).

Fig. 7 | The presence of asbestos in buildings (credit: infobuildenergia.it).

of IAQ is followed by an improvement, or perhaps a non-worsening, of air pollution, due to stricter regulations on pollutant emissions and the reduction of vehicle traffic.

The IAQ is not a new chapter of risk conditions linked to particular chemical or biological changes in the air, and it adds to those already known in the history of public hygiene and which have concerned the relationship between environmental conditions, the built environment and the individual: health requirements, risks from air pollution and safety in the workplace. The possibility that it is the home that poses a threat to its occupants is an unpleasant idea, but not a new one, as evidenced by the literature on building hygiene aimed at containing epidemics and diseases in place of overcrowding in confined spaces or the presence of hazardous conditions. Diseases such as rickets, tuberculosis, various forms of rheumatism and lung diseases found ideal conditions for development in cold, damp environments where sunlight rarely entered. The relationship between the built environment and disease gave rise to the concept of public health, which led, centuries later, to modern urban planning and hygiene regulations.

The contribution does not go into detail but recognises the historical evolution of the topic, starting with the Roman-era ordinances on the maximum height of buildings and continuing with Vitruvius' (2008), Alberti's (1966) and Broggi's (1888) proposals on the hygiene, healthiness and decorum of dwellings, up to the rationalist ideology of air, light and greenery. As early as the 18th century, Lavoisier sensed that the by-products of organic tissue combustion expelled through the respiratory tract, consisting mainly of carbon dioxide and reduced oxygen content, were the causes of stale air (Kimball, 1929). This hypothesis was disproved in the middle of the last century by experimental evidence, which showed that under normal room occupancy conditions, the CO_2 level in the confined air never registered values for which it could be harmful (≈ 5%) and that in the case of crowding, the discomfort and discomfort affecting the occupants was felt much earlier than the limiting CO_2 values. It was realised that air pollution depended on the production of volatile organic products (VOCs), which are linked to the presence of humans in the environment. Called 'anthropotoxins' by the hygienists Brown-Sequard and D'Arsonval, they consisted of gases excreted by the lungs, the products of skin perspiration and sweating, and were therefore difficult to measure. With the development of industrial production processes, the attention of hygienists shifted to working environments by assuming high concentrations of pollutants and identifying the exposure risks to which people were subjected, defining the technical and regulatory precautions to be taken (De Capua, 2019).

The IAQ debate focused more on industrial cities, working-class neighbourhoods and production sites, where the main causes of pollution were found (De Capua, 2019) to optimise production by controlling the thermal, humidity and ventilation conditions of the environments. That this then contributed to decreasing the number of infections and illnesses contracted at work is incidental and much more will have to pass before this requirement becomes a right for workers and a regulatory requirement. Another reason for the deepening of IAQ control in industrial settings (Figg. 3-6) is the fact that production processes release high concentrations of pollutants into the environment. In contrast, dwellings have been the subject of study in terms of IAQ for little

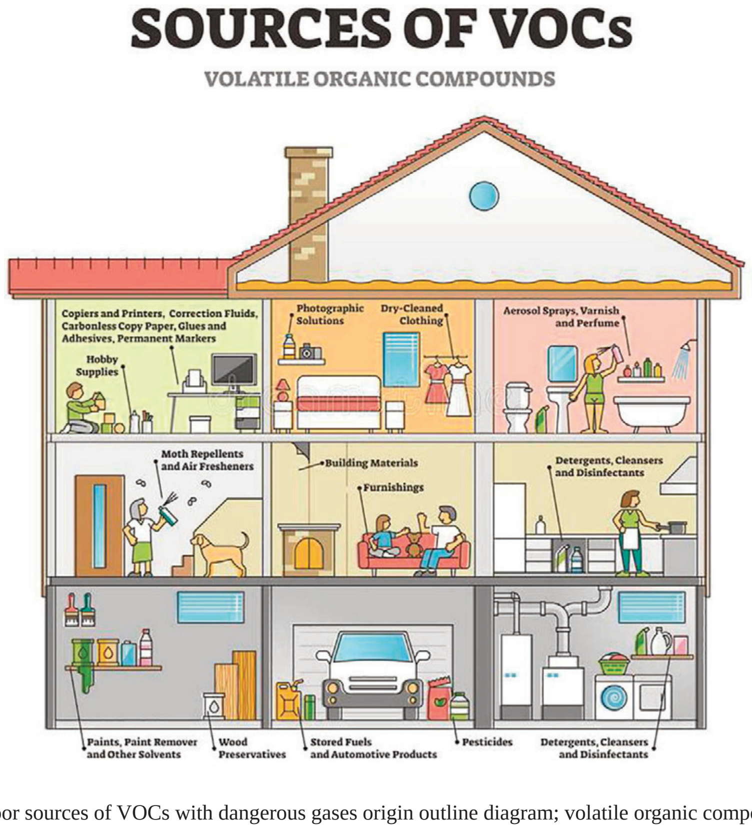


Fig. 8 | Indoor sources of VOCs with dangerous gases origin outline diagram; volatile organic compounds chemical toxic vapour from daily home items (credit: alen.com).

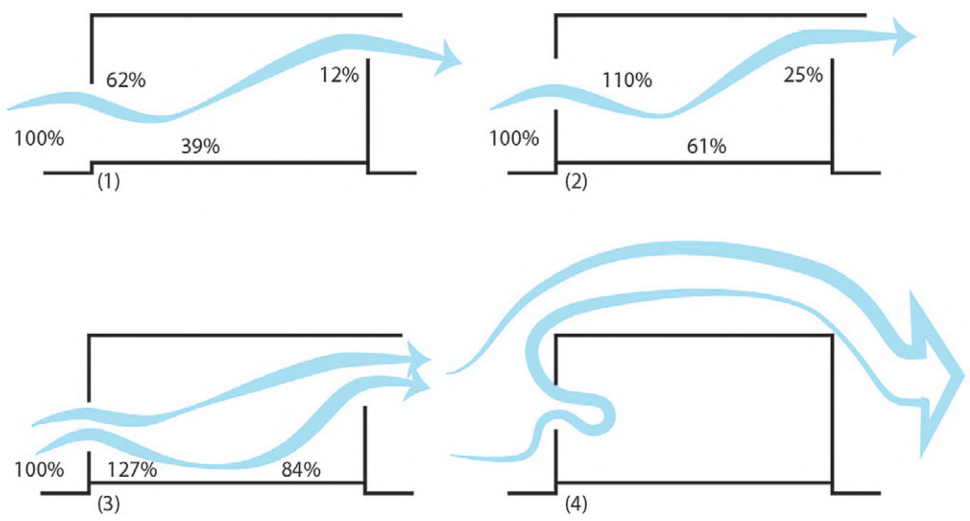


Fig. 9 | Location of inlet and outlet flow openings (credit: A. De Capua and L. Errante).

more than thirty years (De Capua, 2008) and, also to recent health issues, appears to be a field of investigation that has not been fully explored.

IAQ field embraces disciplines and skills required for an analytical approach and trans-scalar intervention strategies. Also, this represents the main obstacle to the implementation of design strategies and regulatory tools, at least in Italy, while in other countries the debate has produced greater results. The regulatory framework is evolving slowly, and although there are decrees and Community Directives concerning IAQ, the Ministries of the Environment and Health have indicated guidelines for research, design and experimental activities to support and promote legislative interventions (De Capua, 2008). Italian regulatory framework is limited to a few specific issues: the ban on smoking in public places to combat passive smoking; decontamination from asbestos (Fig. 7); the use of substances that can produce VOCs (Fig. 8). For other types of pollutants, the government has drawn up recommendations and information documents on health risks (Fig. 9).

The complexity of the topic requires a multi-sectoral approach to capture the variables and translate them into regulatory control indicators on an inter-ministerial, inter-administrative and inter-scalar basis. For example, public administrations and municipalities responsible for building regulations should participate in strategic and regulatory planning to determine the criteria and methods of control. Traditional regulation, fragmented in sectors (building, sanitation, workplace and production) does not have tools to deal with IAQ, environmental design, control or prevention of the healthiness of buildings. This is also due to the attitude of considering the building by

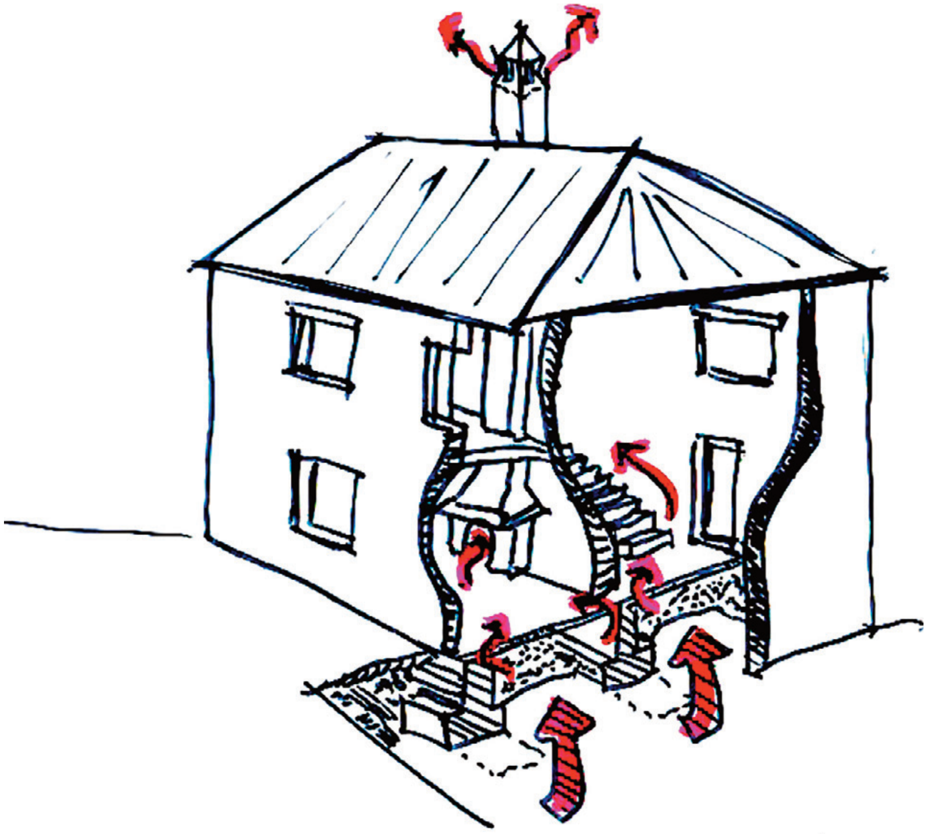
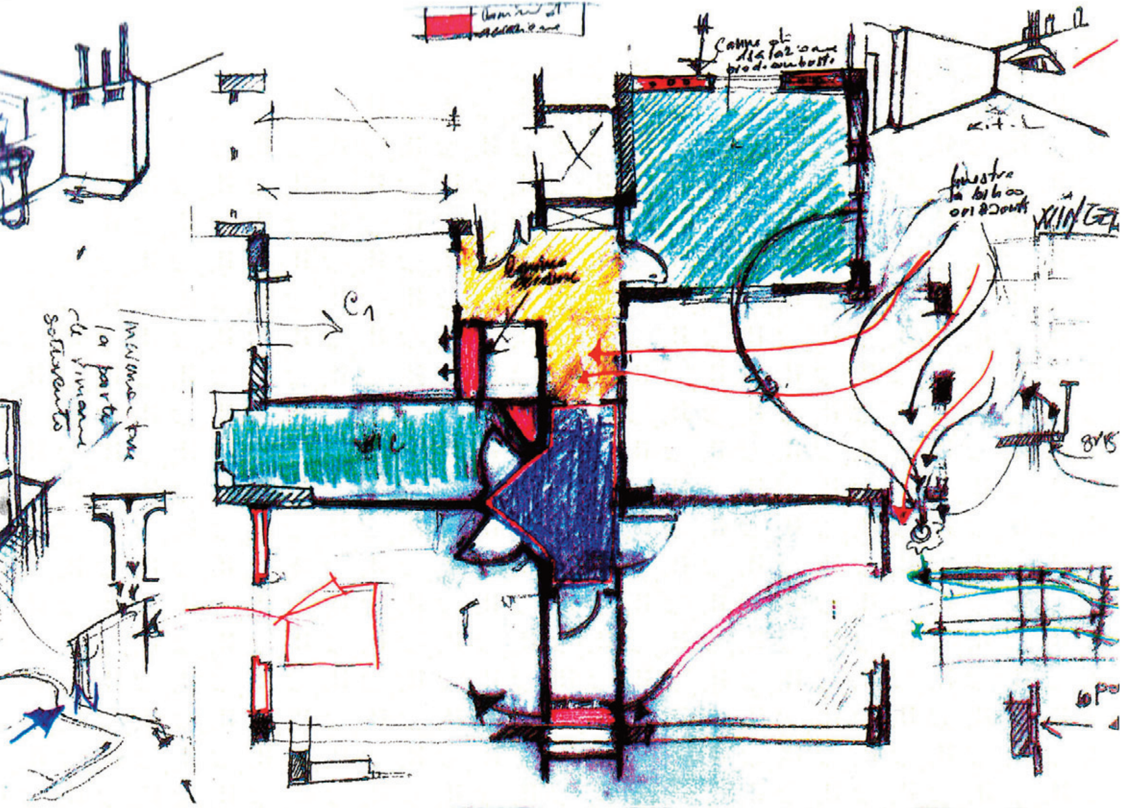


Fig. 10 | Radon infiltration (credit: A. De Capua).

Fig. 11 | Anti-radon membrane, corner kit (credit: brooksonline.ie).



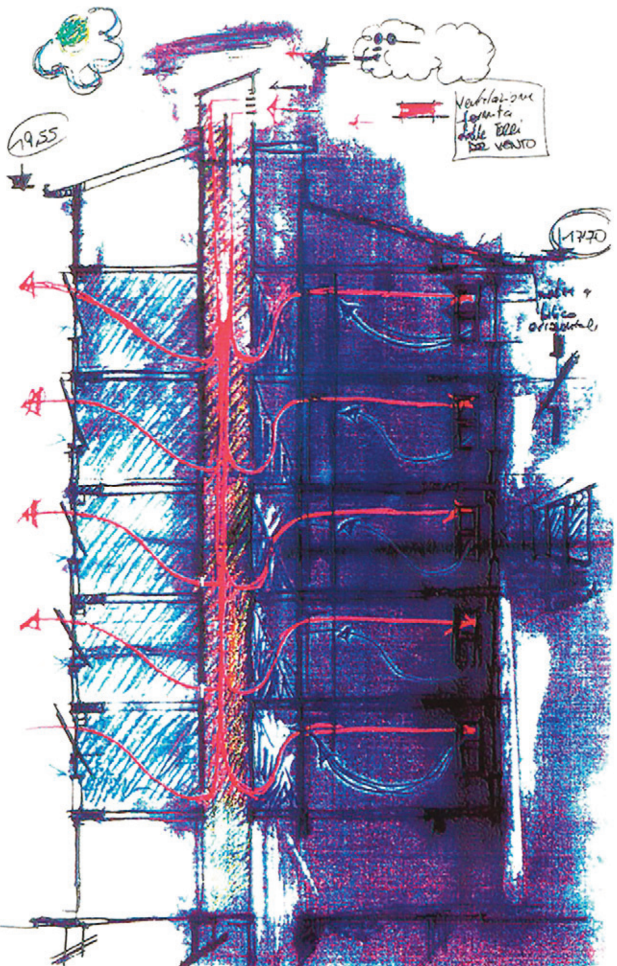


Fig. 12 | Case study, floor plan (credit: A. De Capua).

Fig. 13 | Case study, section (credit: A. De Capua).

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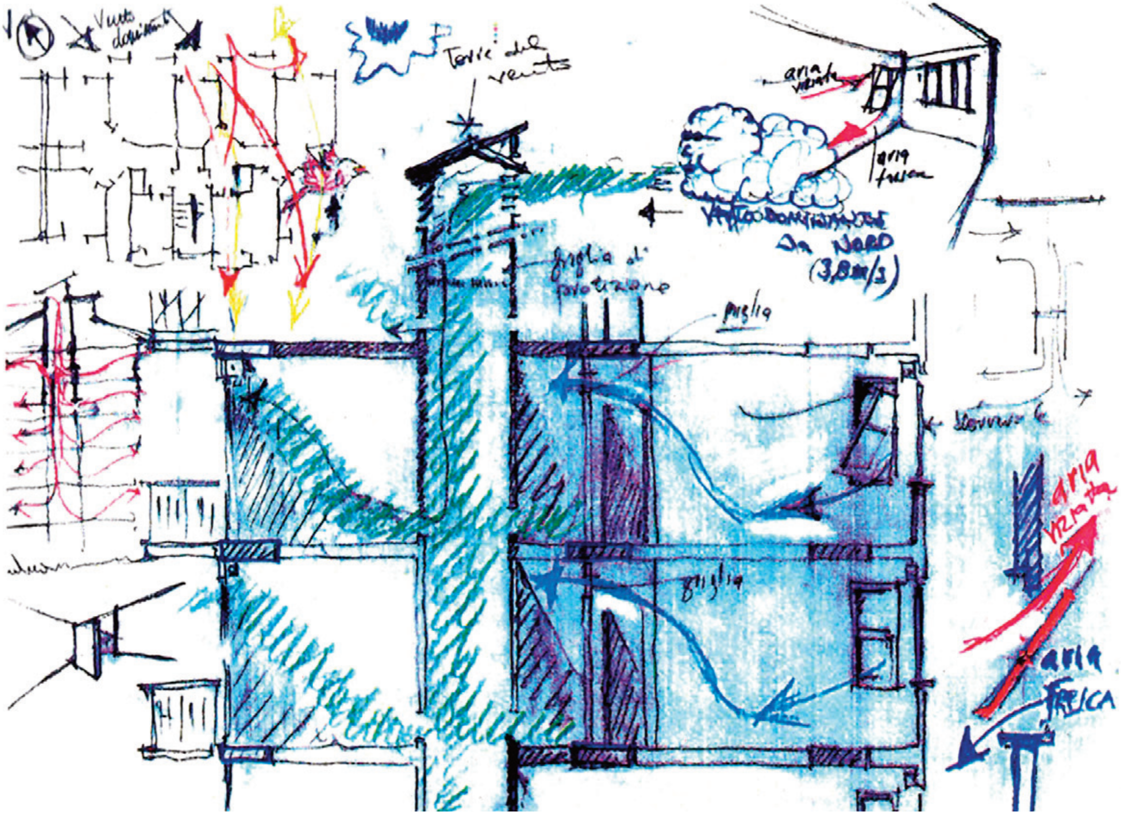
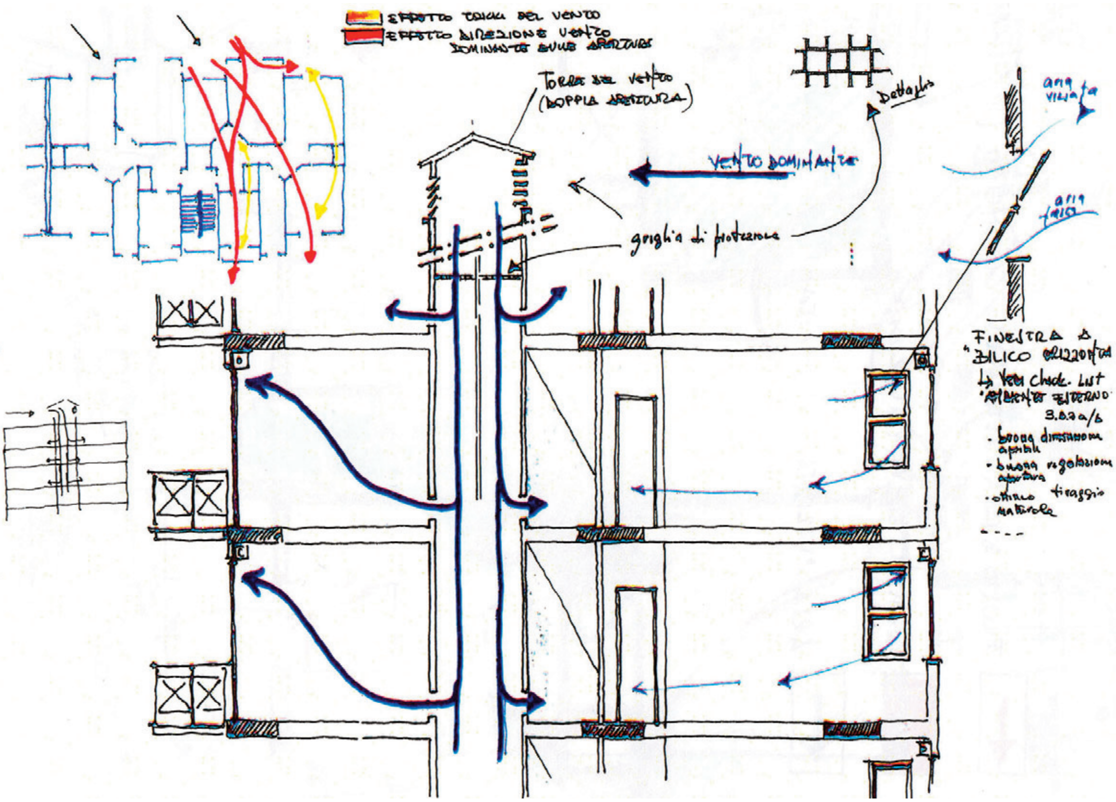
Fig. 14 | Case study, section (credit: A. De Capua).

Fig. 15 | Case study, section (credit: A. De Capua).


Torre del vento
aria viziata
aria fresca
VENTO DOMINANTE DA NORD (3,8 m/s)
griglia di protezione
griglia
aria viziata
aria FRESCA


EFFETTO DIREZIONE VENTO DOMINANTE SULLE APERTURE
TORRE DEL VENTO (DOPPIA APERTURA)
Dettaglio
VENTO DOMINANTE
griglia di protezione
aria viziata
aria fresca
FINESTRA A BILICO ORIZZONTALE

thematic areas and not as an organism (fire protection, sound insulation, moisture insulation, etc.) not considering the correlations between the many subsystems. This limits, if not prevents, an organic view of IAQ by parts and systems, and the involvement of specialists in the various fields (doctors, designers, manufacturers, chemists, etc.). Together with subject-specific standards that have not yet been regulated, it will be useful to revise existing standards in the hygiene and building sector to integrate tools for controlling IAQ.

It is reported that IAQ standards for workplaces are not scalable to other contexts and cannot be used as a reference, due to the peculiarities of the activities carried out and the morphology of the spaces themselves, which are very different from those in the home. The efforts in this field should be directed towards: interpreting current building regulations from the point of view of the effects they have on indoor air quality; documenting and critically reading the measures issued by other countries, which are more advanced in the study of indoor pollution; defining design rules and control methods; drafting or revising building regulations and prevention standards on the health and safety of homes.

Traditional prescriptions for environmental requirements do not guarantee the final quality of buildings and are often conditional on specific technological solutions. The same applies to performance standards, for which it is not yet possible to find indications for IAQ except in outdated regulations. The urgency lies in the fact that, in addition to air pollution and environmental damage on a global scale, the pandemic has brought indoor pollution to the centre of attention, making us rethink the impact on health. Long-term exposure promotes the onset of cardiovascular disease and increases the case of lung cancer. In the short term, the risk is the aggravation of respiratory diseases. In this sense, research should question the health outcomes of over-insulating buildings for energy efficiency reasons.

Controlling IAQ | The issue of IAQ is highly topical since most of the population spends most of their day in confined environments – be it the home, the office or a place of leisure or commerce. This attention is also motivated by increasing health concerns. According to Piardi (1990), the increasing complexity of the production process has also made it complicated to understand the interrelationships between different technical acts. The increasing use of inorganic chemical materials in industrial processes has brought hundreds of new materials into the construction field that should have perfected living and building. Instead, it has happened that the large quantity of new substances and materials has made it difficult to control the quality of the built environment, both concerning the building organism and its response to the needs of users.

Phenomena as speculative building and unrestrained urbanisation for economic growth without environmental or social compromises, and the design of such building complexes do not respond to criteria of internal or external environmental well-being for the inhabitants, neglecting even basic design criteria such as ventilation and natural lighting and their physical and psychological benefits. The rush to build at a lower cost of labour implies to use of materials easier to find but often unexplored. The spread of do-it-yourself has made potentially dangerous products accessible to the common people. These actions, individually and in their combinations, threatened IAQ.

In this sense, inside buildings, public or private, polluting conditions can occur even worse than outside, the causes of which must be identified to contain, reduce or eliminate the source. Technological evolution, which has participated in the progressive worsening of IAQ, can compensate with adequate quality control systems for the built environment and appropriate analysis of the occupants' needs and performance concerning the construction techniques to be adopted, including traditional ones. This perspective is connected to the need to formulate environmental, performance and hygiene requirements that can be integrated into the entire design and construction process, conception, information, technological and regulatory control. According to Nardi (1990), design is decisive both for the causes of discomfort and alternative interventions of prevention and resolution.

Designing a healthy building implies that different actors work together to control the performance according to environmental, normative and social requirements at all stages of the design process. The designer directs the performance of the building by reducing the risks of internal pollution, intervening in the control of factors that worsen IAQ and the reduction (choice of products) and confinement (design of plant location) of sources and dilution of concentrations (design of ventilation) and expulsion (devices for evacuation) of pollutants. The location, orientation, size, shape and envelope of the building, which interact with the air-conditioning systems and energy containment techniques, also need to be verified with their indirect harmfulness as a key factor. It is pivotal to set up a rigorous design procedure with assessment tools to exclude or minimise mistakes in IAQ with different levels of complexity. Checklists, lists of items and operations should be helpful to interrelated design models with design parameters assessed according to contextual conditions. This interdisciplinary process involves actors with specific skills for each control phase (Berglund et alii, 1991) to interpret the data collected and their mutual influence on IAQ.

An IAQ control tool does not limit the designer but empowers him to develop more effective solutions. Theoretical models define the problem from several points of view, noting that the main factors lie in four categories (Molina et alii, 1989): 1) Physical (temperature, relative humidity, ventilation, artificial lighting, noise, ions, fibres and particulate matter are those covered by national and international recommendations and relate to standards that must be met; 2) Chemical (ETS, formaldehyde, VOCs, biocides, CO_2, CO, NO_2, O_3, SO_2) which, too numerous to be considered individually, are usually classified into those emitted indoors and those from outside; 3) Biological (Microorganisms, bacteria, etc.); 4) Psychological.

Conclusions | Updating living quality regulations implies a general awareness of the cultural evolution of the concept of healthiness in renovation, redevelopment and new construction, integrating quality and performance control tools into the process. IAQ is the challenge of the near future, together with the renovation of minor historic centres, two themes that are often parallel when considering the difficulty of adapting older buildings to the norms of Building Regulations and housing or performance standards. Today, in building transformation interventions, technical choices pursue acceptable habitability conditions (Figg. 12-15), and IAQ is the basis of this condition. Recovery, then, is the revitalisation of the existing, restoring the built environment towards well-being, quality of life and liveability.

The perspective adopted in this contribution takes note of the profound transformation that has affected the field of building regulation, design and construction techniques as a whole, towards a renewed approach oriented towards the formulation of analysis or design support tools for controlling and monitoring IAQ. These topics are relatively new professional interests, hoping in the future for a shift from the methodological rigour of academic research to concrete tools for design control. The multi-disciplinary nature of the issue is a slowing factor, ranging from chemistry to physics, architecture to medicine, and climatology to materials science. On the other hand, the domestic sphere as a field of study and data collection makes it difficult to control the behaviour of inhabitants concerning material choices in design or integrated over time, often through a 'do-it-yourself' approach. Moreover, even when research has addressed the issue (see CR1752:1998 – Ventilation for buildings – Design criteria for the indoor environment), there have been no decisive spin-offs to the construction industry.

The authors are currently involved in a working group at the Department of Engineering of the 'Mediterranea' University of Reggio Calabria with a research unit on indoor pollution control, in the iCare project aimed at the realisation of an ICT Platform for home monitoring and techniques to improve the quality of life of patients.

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VULTURE PARK LIVING LAB
A people-based cultural lab for the Vulture Regional Park

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ABSTRACT
The Vulture Regional Park is unique from a geomorphological point of view and provides an opportunity to experiment with the concept of participation and community. It represents an ideal and privileged 'design yard' for experimenting with an 'ecological conversion of socio-territorial models' and, at the same time, it provides a significant scientific challenge for the study of a Rural and Creativity Living Lab, enhanced through a 'place-based' and 'people-oriented' approach that is applied to a park for the first time in the history of Living Labs. The main objective of this essay is, therefore, to present the Living Lab model that the University of Naples is about to implement in the context of the Vulture Park, through a pilot project highly focused on the needs of the inhabitants of Basilicata, to assess its contribution to sustainable rural development. The paper argues that (the element) of community and cultural identity should be considered an essential element to enable sustainable living.

KEYWORDS
the nature park, participation, regeneration, living lab, sustainability

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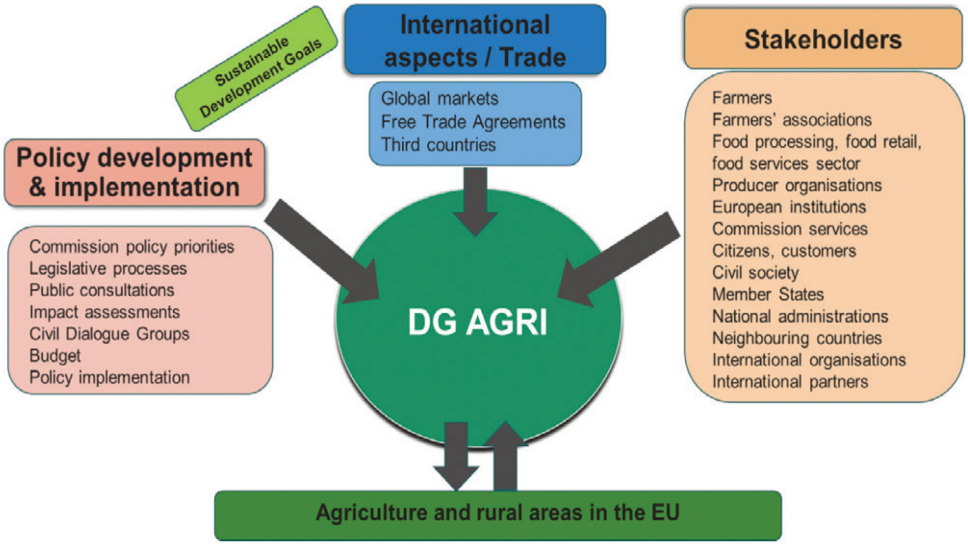
With the advent of the new millennium, landscape, town planning, architecture and design are increasingly assumed to be parts of a unified territorial system (Tesoriere, 2020). In this perspective, however, it is also essential to apply a transdisciplinary approach that considers the cultural and social transformations and contaminations of the communities living in the territory (Nicolescu, 1996). Transdisciplinarity[1] must necessarily be the scientific basis for territorial and green resource regeneration. Only through dialogue, connection and sharing of different knowledge will it be possible to innovate; in fact, if the foundation of cultural heritage is the 'generation' of territory and landscapes, the witnessing of what it has given and how it has influenced the identity of those who live it is its re-generation (Sica, 2016). One can understand how modern social innovation practices must be based on multiple dimensions of sustainability, not only the territorial ones but also the economic, social, cultural and environmental ones (Sica, 2021).

As an illustration of this, the European Union's current rural development policy (European Commission, 2021) is based on a history of activity that recognises the fundamental role and benefits that innovation and creativity offer to citizens in rural areas (Figg. 1, 2), as well as to the broader users of the European landscape (Sereni, 1972). Strengthening European cultural identity is not a rhetorical necessity. It is a clear primary policy objective that has even been included in the EU strategic guidelines for rural development (Sica, 2021). For example, President von der Leyen, in defining the objectives of the Recovery and Resilience Facility, identified economic, social and territorial cohesion as a primary mission, even before 'green' and 'digital' (European Commission, 2021). To meet this challenge, the role of cultural and territorial resources and the cultural industry comes into force as a social, political and economic lever: an effective means to amplify 'marginal' voices.

This type of innovation also overcomes outdated concepts of innovation linked exclusively to the technological component, such as the Smart City (ENoLL, 2020). The main objective is to have a positive social impact on a community of reference, with the ultimate goal of improving the quality of life of the individuals in it. For this reason, social innovation must become the primary driver of territorial development, replacing the classic economic drivers that have driven the sector so far. Moreover, innovation must be considered a crucial factor in promoting sustainable development systems that foster a balance between economic growth and the protection of 'public goods' such as biodiversity and other environmental resources (Santoriello, 2021). Finally, creative thinking is also essential for rural development practitioners and policymakers engaged in addressing critical issues such as competitiveness, quality of life, diversification and territorial cohesion (Calvaresi, 2016). One of the most successful examples of innovative, creative thinking involving the population of rural areas is the Living Labs: open innovation environments in real contexts led by the user who is fully integrated into the co-creation process of new services, products and social infrastructures (González-Méndez et alii, 2021); this also allows the creation of collabora-



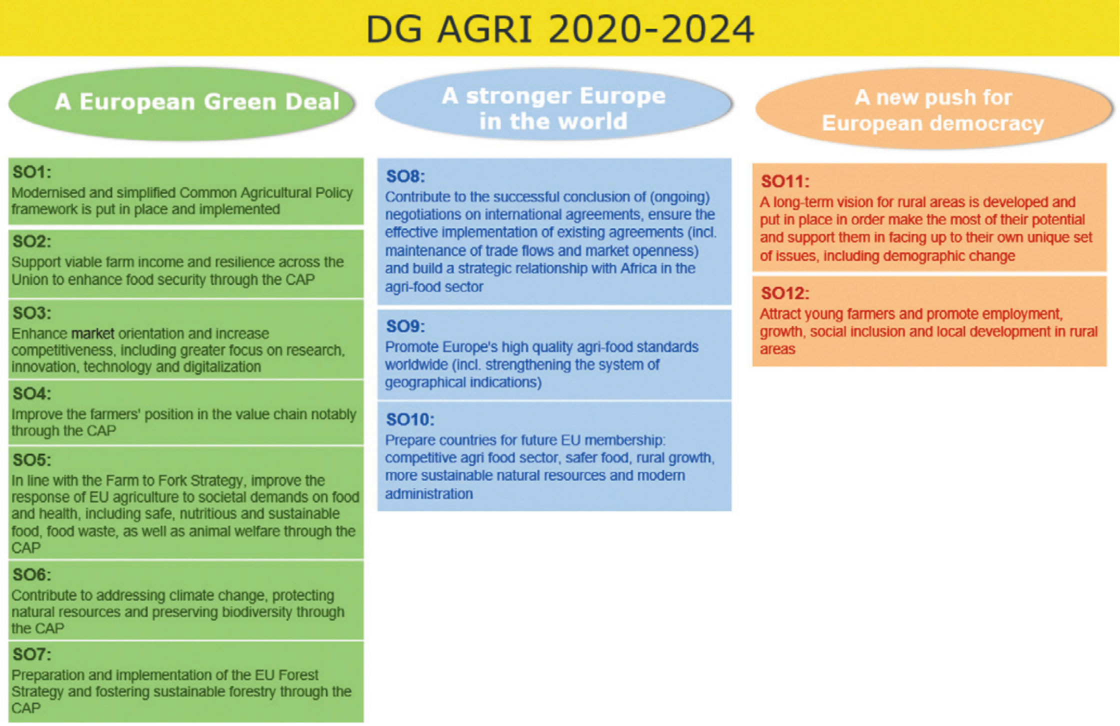


Fig. 1 | General EU direction for the rural development (source: ec.europa.eu, 2021).

Fig. 2 | Recommendations of the DG AGRI 2020-24 (source: ec.europa.eu, 2021).

tive networks at local, transregional and intersocial levels (Cattivelli, 2021). The Living Lab model is schematised in Figure 3.

This brief essay will present the case study of the Vulture Park as a practical application of the Living Lab model, highlighting the current project for the development of 4 different rural creativity poles within the largest natural park in the rural area of the Basilicata Region, recently initiated by the L.U.P.T. (Laboratory of Urbanism and Territorial Planning) Interdepartmental Research Centre at the 'Federico II' University of Naples. The idea behind the experimentation in the Vulture Park, which is intended as a pilot project to demonstrate the applicability and efficiency of the Living Labs model to rural areas, must be to give value to the identity of the community and the needs of the territory and its inhabitants, while keeping intact the objectives that the public administration proposes in common agreement with the community, in order to arrive at the innovative model of Private and People Partnerships based on the cooperation between communities, public organisations, research and businesses (Arnkil et alii, 2010).

In this regard, the work proposed here is based on a place-based and people-oriented approach that aims to make the Vulture Regional Park a model for the study of and experimentation with a Rural and Creative Lab. The project described in this essay, therefore, describes a 'rural laboratory' focused on the needs of those who use the park and live in the area, in which the economy of inland areas, culture and innovation can be brought to life from a sustainable perspective. After providing the geographical reference context and a brief geo-morphological and social description of the Park, the essay introduces the Living Lab model, its theoretical foundations and the concept of participation. Some international examples in which the Living Lab model has been applied are then briefly presented; next, the Living Lab methodology designed for the Park is introduced, and the proposed hubs and activities are described; finally, the essay reports the conclusions and prospects for this experimentation.

Context of reference | The Vulture Park[2], among the 134 Regional Parks in Italy, is located in an area unique for its geomorphologic and vegetation characteristics. It is characterised by the strong presence of the volcanic massif (Fig. 4), which visually characterises its panoramic and landscape profile, and by the presence of luxuriant vegetation due to the peculiar characteristics of the volcanic geology of the area. The volcano's geology is at the heart of the area's peculiarities. In addition to clearly characterising the morphology, it has determined a wealth of hydrominerary resources, evidenced by the numerous natural mineral springs and particular chemical characterisation of the soils. This allows for the development of flourishing agriculture, driven by particular crops (e.g. vineyards) that have been an essential part of the local economy for centuries. Two lakes are at the heart of the Park (and the volcano); both born in the original crater, they lie at different altitudes and are connected by a channel. The water of the Piccolo thus flows into the Grande, creating different habitats between the two lakes and hence a condition of high and unique ecological value.

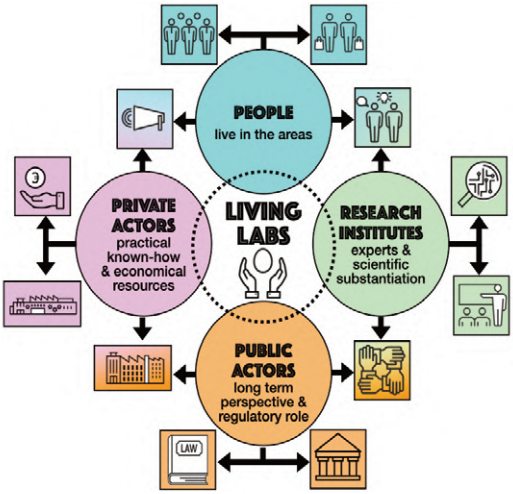


Fig. 3 | The Living Lab Model and its main actors (credit: the author, 2022).

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Fig. 4 | The core of the Vulture Park: the two lakes (source: parcodelvulture.it, 2020).

In addition to its geophysical characteristics, the Park is strategically positioned between Basilicata, Campania and Apulia (Spicciarelli and Marchetto, 2019; Fig. 5). Thanks to its geographical position, the Park has gained a special place in the history of southern Italy. Today it preserves the signs and evidence of different eras, according to the phases of territorialisation and deterritorialisation that have affected it over the centuries (Carella, 2010). The protection and implementation of ecological networks assume a multi-scalar role in the valorisation of systems of ecological, landscape and environmental connection and continuity (Coppola, 2017): from the European level (by uniting European ecological networks), to the local scale, through ecological corridors capable of creating connections between the fragmented portions of the Park and the surrounding natural territory (Coppola, 2016). This theme is fundamental in planning the Park and creating protection and enhancement routes through different strands: blue routes, green routes, etc. (Coppola, 2017).

The Vulture Regional Park is not only unique in terms of geomorphology and history but also allows us to test the concept of participation and community, starting with social, cultural and human stratification. It allows us to test the concept of territorial ‘re-generation’ with a trans-disciplinary approach with a solid socio-cultural aspect based on community participation. Community participation is essential in the case of revitalisation, also from a tourism perspective, where various decisions are made that will have more or less intensity and more or less reversible effects on the local population (De Biase and Calabrò, 2021). The area’s resources’ value and potential must be considered an engine for sustainable development and quality of life in a changing society.

It is necessary to emphasise the importance of a broad knowledge of the resources that must be revalued and defended (Coppola, 2017). It is also essential to rethink territorial assets, especially in regions of social transformation, as resources that must belong totally and with full awareness to the community in which they are found; they represent one of the opportunities for the development of the territorial economy, and a significant opportunity to experiment with good governance practices that require the ability to connect the different forces that insist on a territory. For these reasons, each territory, and especially the Vulture Park, can be considered an ideal and privileged 'planning site' (Sica, 2016) to carry out in-depth research on the cultural identity of society with the diversification of history, religion, art, food and wine, etc. In other words, a 'return to the territory' is desirable, i.e. an 'ecological convergence of socio-territorial models' (Magnaghi, 2020), built from the bottom up through the reconstruction of cognitive, cultural and productive relationships between active citizenship and territorial heritage (Carta, 1999), and of solidarity-based and non-hierarchical relationships between inhabitants, producers and local societies.

The Living Lab | The Living Lab model was first defined in 2003 by the MIT Media Lab, an interdisciplinary research laboratory that encourages the unconventional mixing and matching of seemingly disparate research areas (Schumacher and Feurstein, 2007; Bergvall-Kåreborn et alii, 2009). Since then, and especially in recent years, Living Labs have become a powerful tool to effectively involve the user in all stages of the research, development and innovation process, thus contributing to urban and territorial regeneration locally, as well as nationally and internationally (Schaffers et alii,

Fig. 5 | Strategic position of the Vulture Park (source: ilvulture.it, 2019).

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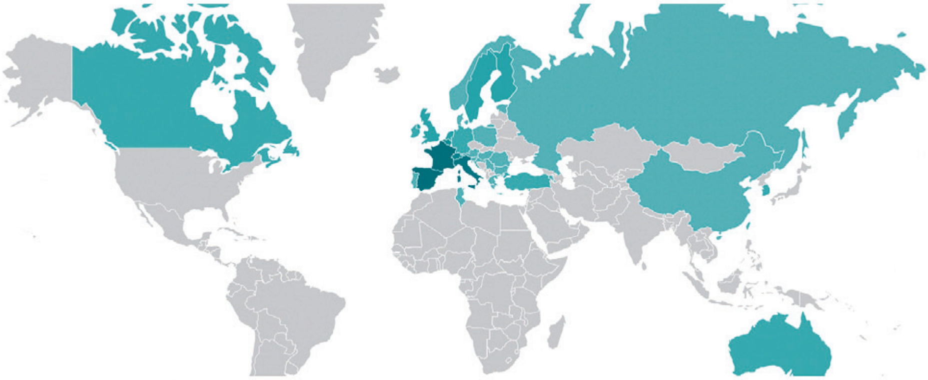
Fig. 6 | Map of the benchmarked Living Labs forming the EnoLL (source: enoll.org, 2022).

2007). 2006 also saw the birth of the European Network of Living Labs, which is now the most significant international, independent, non-profit association of benchmarked Living Labs (with over 480 members; Fig. 6) and aims to promote the Living Lab concept in order to influence European Union policies. However, as shown in this essay, few Living Labs are dedicated to developing inland and rural areas and even fewer built-in forests and parks.

In general, the most innovative aspect of the Living Lab model lies in the fact that it allows active and proactive participation of the community, which has the excellent opportunity to shape the future of the territory in which it lives. Indeed, with the Living Lab model, citizens and communities have the opportunity to express their needs through working groups and activities, and users can generate innovation in the places where they live and thus generate and regenerate them (Cleland et alii, 2012). They are not just testers of a final product but act as project managers at the same level as the other Living Lab partners (Universities and research centres, private and public sector) and have the opportunity to participate in and organise innovation initiatives such as master courses, summer schools or bar camps (Arnkil et alii, 2010). More specifically, the proposal described in this essay constitutes one of the first cases of a completely ‘people-oriented’ Living Lab, in which the structure of the Living Lab itself and all the activities connected to it are created from a highly participative and participatory perspective. Innovation based on active participation is a crucial factor in promoting sustainable development, promoting the balance between economic and social growth. Therefore, Living Labs are a strategic opportunity to move from a Public-Private Partnership formula to a People, Public-Private Partnership (Westerlund and Leminen, 2011; Fig. 7), where open innovation, generation and re-generation are driven directly by users (Nesti, 2015).

Participation: collaborative covenants and heritage communities | Collaborative agreements are the tool to govern the co-design and shared management of activities,



the start-up of new community enterprises and the redevelopment of buildings and public spaces (Arena, 2015). These actions introduce a procedural technique based on 'collaborative dialogue' in that they foster the establishment of non-authoritative (horizontal, collaborative, cooperative) relationships between government and city dwellers and/or the enabling of forms of cooperation between inhabitants and other local actors (Baccarne, Mechant and Schuurman, 2014). This implies that different actors interact on an equal footing, which, in turn, requires new changes in the action and mentality of public, social and private actors. The public administration thus becomes a platform for fostering the construction of these cooperative relationships between the different urban actors. The practice of entering into collaboration pacts aims to be a 'push' between communities and other local actors ready to take a level of risk and invest a significant amount of time as 'civic entrepreneurs'. Thus, collaborative pacts represent a novel form of institutional innovation and public governance that leverages a non-authoritarian form of city government action.

Pacts should enable active citizenship and collective action by inhabitants as a new way of governing and managing urban resources, services and local infrastructure. There are three possible forms of pacts: 1) Pacts concerning disused buildings made available for redevelopment and the creation of new services and activities; 2) Pacts concerning public places (schools, social and welfare services, cultural spaces, etc.) that have a more significant potential for use than the current ones; 3) Pacts promoting the shared care and use of public spaces, green areas, underused facilities, also proposed by citizens (art. 118, para. 4, Const.; Regulations on the shared administration of common goods; Siza, 2015).

The heritage community is defined as a group of people who value the identity and characterisation of cultural heritage and who are committed, within the framework of public action, to sustaining and passing on the contents and expressions of heritage to future generations (Bindi, 2019). Belonging to a heritage community is, therefore, linked to the fact that all the people who belong to it recognise a value in the cultural

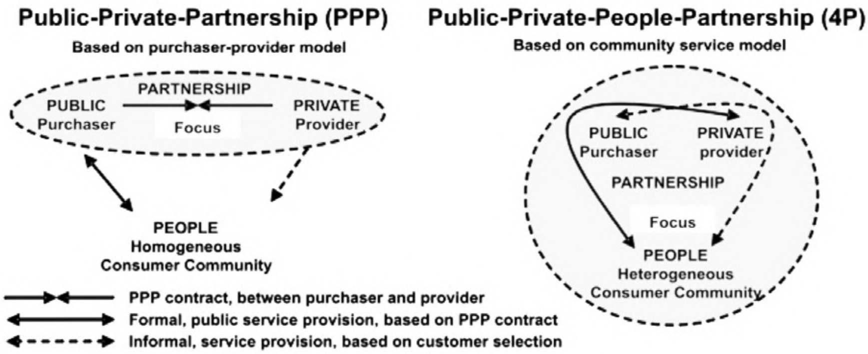


Fig. 7 | From the PPP to the 4P model (source: balticurabanlab.eu, 2020).

Fig. 8 | SIMRA partners and logos (source: simra-h2020.eu, 2018).

heritage they have helped to define and safeguard. Heritage communities are committed to representing, transmitting and enhancing this value without discrimination or selectivity based on ethnicity, class or geographical location with all forms of expression and communication channels at their disposal, including the most advanced and performative digital technologies.

The idea of heritage as shared cultural capital and as a fundamental right of citizens proceeds with the empowerment of heritage community actors as direct bearers and custodians of heritage (Sica, 2020). Recognizing the heritage of communities around cultural resources and identities sets the context for dialogue and alternative conflict resolution. This enables the development of intercultural policy dialogue, democratic debate and cultural inclusiveness. At the same time, it becomes necessary to use the knowledge and skills learnt and passed on as development resources and actively involve the Member States in a community and participatory approach, such as Living Labs, to heritage care.

The international scenario: three examples of Rural Living Labs in Europe | The innovation potential of rural areas and parks is part of the European Commission’s plan to develop a long-term vision for inland and rural areas. Nevertheless, and despite the many successful applications of Living Labs in the European landscape, there are still too few EU-funded projects within the Horizon 2020 programme that have dedicated capacity and expertise to address the problems of rural and green areas to improve their potential, seize the opportunities they offer and contribute to Europe’s future. As an example, in this section, some international projects relevant to the argumentation on the importance of the concept of Rural Living Labs are introduced and briefly described. It is pointed out that the pilot programme proposed in this essay is among the very first to bring the ‘placed-based and people-oriented’ Living Lab methodology into a Park.

The Project Social Innovation in Marginalised Rural Areas[3] (Fig. 8) The main objective of the SIMRA Project is to study, through numerous case studies, the notion of social innovation and innovative governance in the agricultural and forestry sectors and to then be able to promote these sectors in rural areas in the Mediterranean regions of Europe and beyond (Secco et alii, 2019). Specifically, the Project partners (including 4 Italian entities) analysed 24 regions and 7 innovation actions, divided into 8 work packages (Fig. 9), to provide concrete solutions to address the challenges of marginalised rural areas. The topics covered included forest management, social agriculture, local development, energy, child and health care and social networking. The final product produced by SIMRA is a systematic collection of empirical evidence of the drivers, processes, outcomes and impacts of social innovations in Europe, North Africa and the French Caribbean. The main strength of this Project is the systematic work carried out on a statistical sample of case studies that allowed the construction of a solid theoretical and operational framework.

Heritage for Rural Regeneration[4] is a research project that establishes a new paradigm of heritage-led rural regeneration, capable of transforming rural areas into demonstration laboratories of sustainable development through valorising their potential. Ruritage has identified 6 Systemic Innovation Areas (pilgrimages; sustainable local food production; migration; art and festivals; resilience; integrated landscape management, Fig. 10) that, integrated with transversal themes, show the potential of heritage as a powerful engine for the economic, social and environmental development of rural areas (De Luca et alii, 2021). The knowledge, constructed in 14 Role Models (RM) and assimilated within the project, was transferred to 6 Replicators (R) across Europe and led to the development of the Ruritage Atlas (an integrated and interactive web-based atlas capable of mapping territories based on human-landscape interactions), of Ruritage Replicator Tool Box & My Cult-Rural Toolkit (a comprehensive set of good practices and innovative solutions for rural regeneration), Ruritage Serious Games kit, DSS, and Regeneration Guidelines (a wide range of tools to promote change and gather feedback from rural communities).

The project Living Lab research concept in Rural Areas[5] (Fig. 11), coordinated by the Spanish Fundaction Universitaria San Antonio (UCAM), put the Living Lab concept at the forefront of rural development in thirteen Living Lab initiatives in selected pilot areas in eleven countries (Portugal, Azores, Czech Republic, Slovenia, Spain, Malta, Turkey, Italy, Latvia, Austria, France and Tunisia; Fig. 12). The project identifies Living Labs as innovative business models that are currently being developed in rural areas as they foster a more sustainable mobilisation of resources, better cooperation between actors along the value chain and lead to new services. Living Labs broadly use the concept of open innovation, with success/failure rates determined by key empirical research factors. The main objective of the LiveRur project is to improve the knowledge of business models developed in rural areas, including understanding their potential.

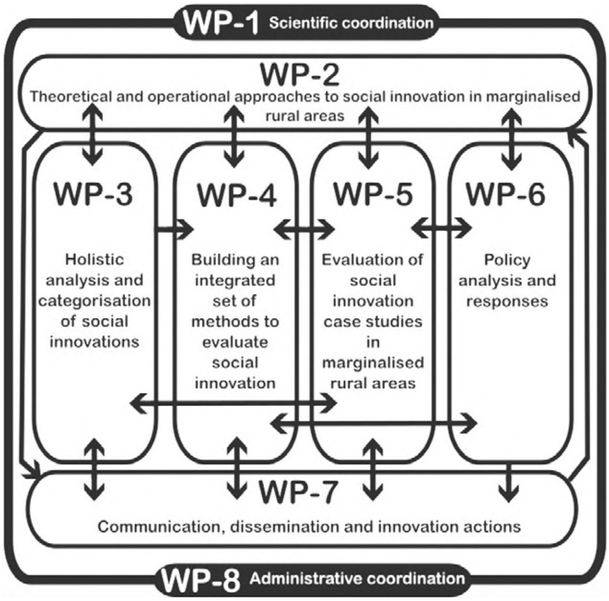


Fig. 9 | SIMRA work packages (source: simra-h2020.eu, 2018).

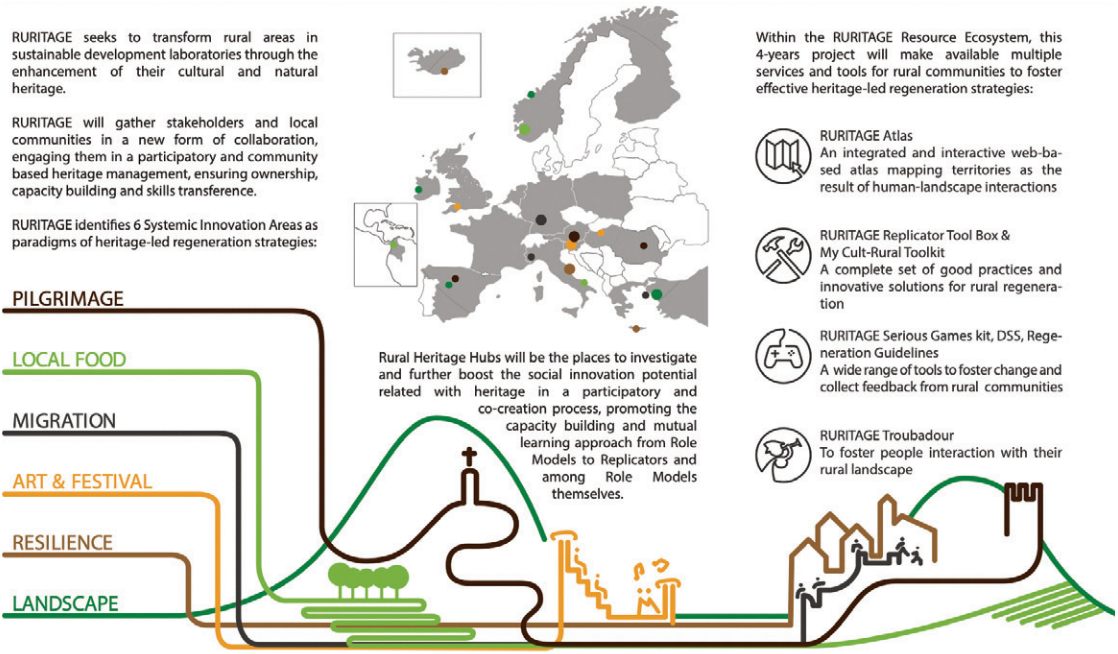


Fig. 10 | RURITAGE: objectives, partners and outcomes (source: ruritage.eu, 2020).

The Living Lab methodology for the Vulture Park: between experimentation and open laboratory | The experimentation of the Living Lab methodology in the Vulture Park starts from the experience of the PRIN Smart Open Urban-rural Innovation Data[6] project and its associated projects but goes beyond the spatial dimension of the city. It aims to understand how the connection of the urban/territorial dimension with the place-based innovation approach determines 'nodes' (Porter, 1983) as activators of innovation and knowledge. We aim to make the Vulture Regional Park a model for the study and experimentation of a Rural and Creative Laboratory but give it a transdisciplinary aspect (Nicolescu, 2008) with a 'place-based and people-oriented approach (Pierson and Lievens, 2005). The Living Lab model, in this case, will therefore be applied as a 'rural laboratory' where inland economy, culture and innovation live in a sustainable perspective as a heritage community (European Commission, 2009). From this point of view, ethical production and consumption solutions inspired by the organisational model of community-based social enterprises play a fundamental role (Chiarullo, Colangelo and De Filippo, 2016).

Figure 13 presents a schematic diagram of the proposed model for the park, which was designed with a 'bottom-up' approach: it started from the needs of the population to build something that would increase the sense of community and belonging. The project is in its early stages, with no concrete results or timeline. However, in the following section, a thorough description of the four main hubs that have been identified as possible Living Labs in the Vulture Regional Park is provided, briefly highlighting their methodology and planning, their target audience, the actors involved in them, as well as their main deliverables and aims (Fig. 14).

Hubs and activities | From a methodological point of view, the Vulture Rural and Creative Lab project path described in this essay will be articulated in activities that are perfectly functional and correlated with each other, starting from the identification of the inhabitants' needs and based on the use of 4 hubs. The main objectives are: a) the creation of a path of participation and engagement to experience the Park and consider it as a public good, also through pacts proposed by citizens that promote the care and shared use of public spaces, green areas and underused facilities (Arena, 2015); b) the participation of the community in decision-making processes that will have effects that are more or less impactful and/or reversible on the local population; c) the creation of spaces for experimenting new generative welfare practices through the hybridisation of culture, citizenship and agriculture and a study centre on 'open innovation' applied to the environment, creativity and sustainability; d) the strengthening of networks between operators in the same sector with related sectors and with actors in the knowledge system, to promote innovation and increase the dissemination of training. The four hubs that will be developed in the Vulture areas are briefly described below.

1) Community Hub – a hub to promote community re-appropriation of physical and relational spaces. A path of Inclusive Governance, capacitation and community involvement to experience the community hub together as a public good. A construction site from below. As the main deliverable of this hub, we envisage the creation of a map of all spaces belonging to the Vulture Park area, including both forests and urban territories. In addition, we aim to use the principle of advocacy whereby several territories can be rented at a low symbolic price by young entrepreneurs under 40 who, in return, undertake to enhance the local supply chain and local products. This allows new industries to flourish, preserving local craftsmanship and regional excellence, and, at the same time, is a remarkable growth and learning process for young entrepreneurs.

2) Rural-cultural hub – a shared experimentation space for new practices of generative well-being through the hybridisation of culture, citizenship and agriculture. The main products of this hub will be community-supported social agriculture and the distribution of products from the fields, co-production storytelling workshops, land research/action, immersive trails and experiential agricultural workshops. In particular, village fairs will be organised with performances such as cooking shows, labyrinths, storytelling, etc. During these fairs, the hub will also provide a space for experts to discuss the situation and possibilities for village development and prospects for urban-rural cooperation in the context of growing urbanism and the global economic crisis. This will certainly also help to improve tourism in the region.

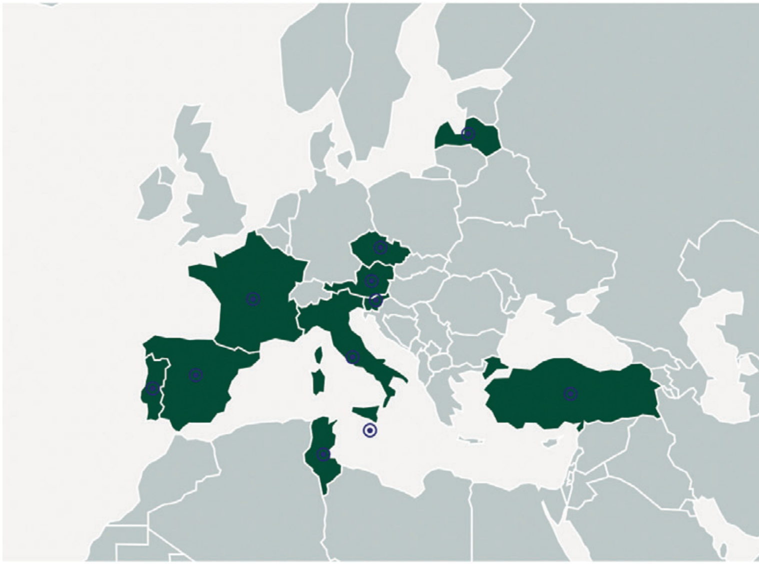


Fig. 11 | LIVERUR: the ecosystem of the project (source: liveru.eu, 2020).

Fig. 12 | The 11 pilot areas of the project LIVERUR (source: liverur.eu, 2022).

3) OpenScience Hub – a study centre on open innovation applied to the environment, creativity, and sustainable development. This hub will be an on-site research observatory enabling the exchange of information and new collaborations between students/researchers and local farmers/citizens/artisans.

4) Creativity Hub – a hub for experimenting with social, cultural and agricultural innovation practices and contributing to the reflection and knowledge produced by communities of change, community hubs and researchers in Italy. The main deliverable of this hub will be the creation and publication of a sharing platform for the development of local economies and the publication of the activities carried out in the other hubs and, more generally, in the Park. An essential objective of this hub and the previous one is mentoring young people under 40, who will also be trained and prepared by researchers and professors from the L.U.P.T. Centre and various Lucanian Universities.

The innovation model based on creativity and participation envisaged for Vulture Park is consistent with the broader trends that define innovation. The main difference from traditional innovation policies lies not so much in the object of the policy but in looking at the innovation-related processes on which the policy acts (Manzini and Staszowski, 2013). Traditional innovation theories describe a linear progression that starts with the idea that is then developed (Barata et alii, 2017).

Risks, limitations and criticalities of the proposal | The Project described is still in the early stages of its development. Therefore, a detailed risk and criticality analysis has not yet been carried out. However, in this paragraph, the most common risks asso-

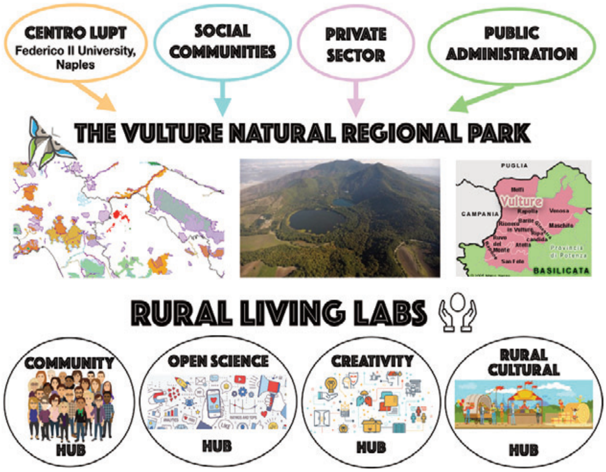


Fig. 13 | Rural and Creativity HUB's model for the Vulture Regional Park (credit: the author, 2022).

ciated with the Living Lab model and its application in rural areas and which could occur in the specific case of Vulture are highlighted in general. Generally speaking, participation within the Living Lab is a fundamental aspect of the project's success and, as such, also represents a risk, which may be logistical (albeit positive) if participation is more significant than expected but predominantly negative if it is lower. As already described in the introduction, for Living Labs to be successful, it is indispensable that there is the active participation of multiple actors, who make their resources (human, financial, assets, etc.) available to the network. It is even more fundamental that the activities are 'inhabitant-friendly' and specifically designed with and for the population basin to which they are dedicated. Therefore, a series of preliminary meetings have been organised between the L.U.P.T. Centre and the park communities to cooperate and co-create activities (Fig. 15).

It is also impossible to establish rigid rules to be imposed on stakeholders for governance. Appropriate communication is therefore indispensable for smooth and elastic planning and properly implementing hubs and activities. Some numerous plans and strategies can be implemented to ensure smooth internal communication between stakeholders and thus avoid problems of poor planning and conflicts: monthly meetings broken down by category rather than by type of partner could facilitate the creation of synergies; quarterly reports that could demonstrate the positive trend (but also highlight the criticalities and aspects that need to be corrected/revised) of the experiments, as well as the professionalism and commitment of the experimenters and stimulate investment also from private individuals; and the creation of a web platform which, if used correctly, has the potential to guarantee the dissemination of all the news concerning Living Labs (new experiments, events, etc.) to all interested Stakeholders quickly and concisely.

As far as governance is concerned, having eliminated the distinction and separa-

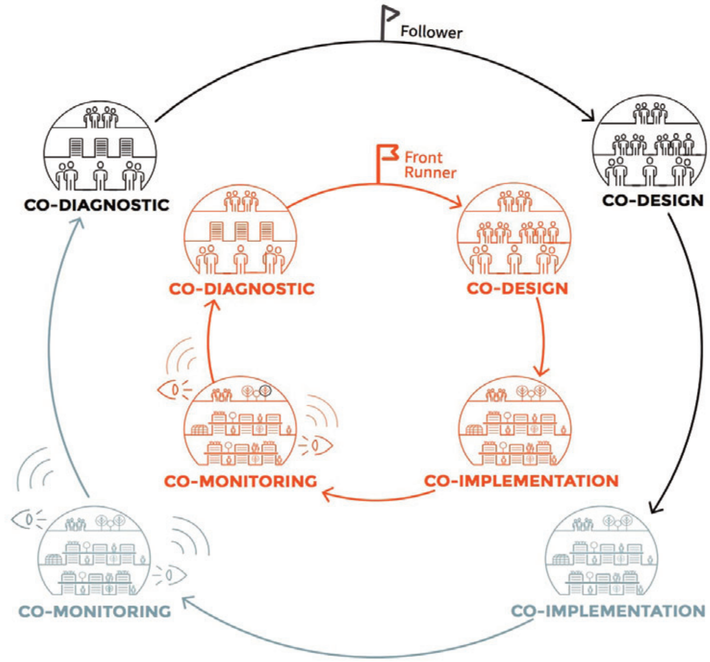


Fig. 14 | From Living Lab to the community: co- design and creation (source: openlivinglabdays.com, 2021).

Fig. 15 | First co-creation moment between the LUPT and the community of the Vulture Park and administrations (source: parcodelvulture.it).

tion between producers and consumers, it is possible to activate a mechanism of equal cooperation that creates the theoretical and methodological infrastructure necessary to unite collaborative pacts and heritage communities (Ballon, Pierson and Delaere, 2005; CoreLabs, 2007). Finally, one of the most outstanding critical issues that must be addressed in the realisation of the project is the availability of funds, both private, from partners and private companies, and public, from research institutions. These funds are indispensable for hiring new personnel, purchasing hardware and software, publicising activities and sharing results. The L.U.P.T. Centre is already moving in this direction, negotiating the allocation of dedicated funds for this pilot programme.

Conclusions and perspectives of research | It is not an exaggeration to say that an ‘invisible cultural revolution’ is taking place today, indicating the beginning of an acceleration phase of economic development based on new technologies and the new centrality of information and knowledge in production processes (Verganti et alii, 2004). The production and consumption of culture favour an enhancement of the social (in terms of community cohesion, quality of human relations, feeling of trust, willingness to cooperate, and sense of territorial identity), which transforms local identity into a key concept for safeguarding the cultural peculiarities of territories. It also establishes a close relationship between creative processes and supports ‘identity policies’ that enhance the cultural authenticity of places (Sica and Lusini, 2021).

The fact that these phenomena occur precisely in the era of economic globalisation confirms the thesis that they represent a natural reaction to cultural homogenisation. The internationalisation of markets strengthens the role of places through a twofold order of consequences. One is social, tending to safeguard and respect the culture, the survival of the most peculiar popular expressions, cultural heritage, and feelings of social belonging. The other is economical and gives new vigour to products with a substantial symbolic value, nourished by details concerning local culture, traditions and taste.

The rural workshop and creativity model addresses the economic, social and environmental resilience of the innermost areas of Vulture; it is therefore proposed as an experiment in inland areas. Directly from the needs of the territories, the need to strengthen and consolidate networks between operators in the same sector with related sectors and with sub-sectors of the knowledge system to promote innovation and internationalisation and to increase the dissemination of training emerges. The experience will also lead to the definition of some pilot cases of heritage communities (European Commission, 2022).

The pilot case described in this essay, which the L.U.P.T. Centre of ‘Federico II’ University of Naples is about to start, fits perfectly into the European horizon. Its main objective is to identify and implement four activity hubs within the rural areas of one of the 134 Regional Parks in Italy, located in an area with incredible geomorphologic and vegetation characteristics. The hubs, conceived and realised ‘from below’, with the active participation of the inhabitants, private and public partners and coordinated by our Research Institute, have the primary purpose of enhancing the park and promoting its care and shared use and thereby also by increasing urban-rural cooperation and contributing to the development of tourism, agriculture and local crafts. Nevertheless, above all, their role is to educate the community so it can play an increasingly active role in decision-making processes, first local, then national, political and international. The idea behind the Vulture Park Rural Creative Hub project, and any other project based on the Living Lab model, must be that of enhancing the identity of the community, and the needs of the territory, while keeping intact the objectives that the public administration proposes in common with the community. Hence the current effort to involve the actual users of the landscape (Tosco, 2007), the people who inhabit it: the Council of Europe Framework Convention on the Value of Cultural Heritage for Society (Council of Europe, 2005), signed by Italy in 2013, considers landscapes as fully belonging to the cultural heritage and able to highlight the cultural essence of the territory. As they enhance the relationship between the environment and communities, they must be self-preserved and their value passed on to future generations.

However, this vision requires a fundamental basis: a broad and complete knowledge of what is necessary to respect, protect and enhance. In particular, contexts such as those of inland areas present differentiated ecological and social forms, with areas still active in their continuity of use but threatened by deconstruction dynamics that grip the territory. Participation must therefore be a way to get the local population more involved and to create an endogenous type of destination management that considers the community's needs. Indeed, within the community, there are shared goals that make it easier to use participation. Participatory economic development focuses on the community itself and thus differs from the traditional approach to economic development that tends instead to attract resources from outside (Beel et alii, 2017).

Notes

1) Transdisciplinarity is a term that first appeared in the 1970s when Jean Piaget (1972) pointed to a stage that should not be limited to recognising interactions or reciprocities through specialised research but should identify those connections within a total system without stable boundaries between the disciplines themselves. In 1994, Basarab Nicolescu, Edgar Morin and Lima De Freitas signed the 15 articles of the Charter of Transdisciplinarity (Nicolescu, 1996), proposing the adoption of an alternative and innovative model of thought aimed at establishing a different concept of reality that is more adequate to understand the modern world. Where scientific reductionism runs on binary logic, they integrate the 'third eye'. In 1985, Nicolescu (2008) proposed a more detailed definition: he introduced the concept of 'beyond' disciplines, both as an etymological adaptation of the prefix 'trans' and from his experience in physics.

2) Vulture's soils, with their strong mining connotations, are a fundamental element of the area's high-quality agriculture. The Aglianico del Vulture vineyards are recognised as a historic rural landscape thanks to evidence of this crop dating back to the 7th-6th centuries BC. Similarly, one of the crops that most characterise the landscape of the volcanic massif is the chestnut groves that cover the

slopes of Vulture, constituting an element with a solid historical-identity value since their management was already regulated within the Constitutions of Melfi in 1231. The value of these aspects has been the subject of numerous landscape protection and conservation measures through the Monticchio constraint ex-art. 136 Italian Legislative Decree 42/2004, the Monticchio Wide Area Landscape Plan and the perimeter of the volcanoes landscape constraint ex-art. 142 lett. l) Italian Legislative Decree 42/2004, to which must be added the environmental protection given by the presence of the Regional Reserve of the Lago Piccolo di Monticchio and the perimeter of the ZSC/ZPS 'Monte Vulture', as well as by Regional Law 9/1984 for the protection of the Vulture hydrominerary basin. The Vulture Natural Regional Park area includes the territories of the municipalities of Atella, Barile, Ginestra, Melfi, Rapolla, and Rionero in Vulture, Ripacandida, Ruvo del Monte and San Fele, with a total extension of 57,496 hectares. With approval resolution no. 129 of 3 February 2016, the Draft Law concerning the 'Institution of the Regional Natural Park of Vulture' with the relative perimeter was approved. The Park occupies 11.3% of the territory of the municipalities involved, with the largest protected areas included by the municipalities of Melfi, 1,553 hectares, about 7.5%, and Ginestra with 1,276 hectares, with 96.6% of the territory in the park area. The park also includes the Natura 2000 Network Sites under the Habitat Directives 92/43/EC and 97/62/EC and Birds Directives 79/409/EC and 2009/147/EC, i.e. the SAC/SPA 'Monte Vulture' (Code IT9210210) and the SCI/SPA 'Lago del Rendina' (Code IT9210201), while the portions of territory on which the SAC 'Grotticelle di Monticchio' (IT9210140) falls are excluded since it includes the 'Grotticelle' State Reserve in the Municipality of Rionero in Vulture, established by Ministerial Decree of 11/09/71, which cannot be included in the Park according to art. 22, paragraph 5 of Law no. 394 of 6 December 1991.

3) For more information see the webpage: simra-h2020.eu/ [Accessed 23 August 2022].

4) For more information, please visit: ruritage.eu/project/ [Accessed 23 August 2022].

5) For more information, please visit: liverur.eu/ [Accessed 23 August 2022].

6) For more information see the webpage: cluds.unirc.it/project/sound-project-smart-open/ [Accessed 23 August 2022].

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FUTURE RURAL LANDSCAPES
The necessary co-evolution between agricultural landscape and energy landscape

Floriana Eterno

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ABSTRACT
This article explores the ongoing transformation process affecting the agricultural and energy landscape. The complexity of the landscape (natural and artificial) in which we live, calls for urgent reflection on how to achieve effective integration between vegetation and the built environment. The landscape has always been subject to mutation. Man and the consequences of his actions have often been the trigger for it. Today we are in a necessary transition phase, especially from an energy point of view. The landscape will change again and this time more quickly because of the urgency imposed by the new policies implemented (European Green Deal, NRRP, etc.). The article emphasises the indispensable process of formal co-evolution between architectural or built elements and agrarian vegetation to guide research into the problems of future agricultural territories, which must be guided by a new and conscious relationship between architectural forms and plant form.

KEYWORDS
agrarian mosaic, form, agriculture, energy landscape, rural landscape

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The consequences of climate change on our planet are now visible. Much of the damage caused by the continuing rise in the global average temperature, due to anthropogenic greenhouse gas emissions, is now permanent and the repercussions on the ecosystems of our planet will soon be irreversible. In the IPCC Working Group II report – Climate Change 2022 – Impacts, Adaptation and Vulnerability, it was pointed out that increasing heatwaves and droughts are exceeding the tolerance thresholds of plants and animals, inevitably leading to the mortality of many species. These events are becoming increasingly difficult to manage, and the report makes it clear that if we are to avoid environmental catastrophe, we only have few years left. António Guterres[1], Secretary-General of the United Nations, stated that «Unchecked carbon pollution is forcing the world's most vulnerable on a frog march to destruction – now. The facts are undeniable. This abdication of leadership is criminal. The world's biggest polluters are guilty of arson of our only home. It is essential to meet the goal of limiting global temperature rise to 1.5 degrees» during the press conference launching the IPCC report. We are at the point of no return. Accelerating the phase-out of coal and fossil fuels by implementing a fair and sustainable energy transition, based on the use of renewable energy, is the only direction to go today.

When we speak of energy transition, we inevitably speak of landscape transition, since the use of energy resources certainly does not occur in an 'aspatial' vacuum but directly involves the territorial dimension (Puttilli, 2014). The landscape will be inevitably subject to new development characterised by the replacement of pre-existing formal values with other values responding to the new conditions. The energy landscape – characterised by thermoelectric and nuclear power plants, overhead power lines, gas pipelines, fuel distributors, photovoltaic panels, wind turbines or simply by the diffuse street lightning – profoundly modifies the landscape by acting on the scenic, aesthetic and identity values of the places involved (Fig. 1). The difficult environmental situation is speeding up these processes of transformation. The imminent planning opportunities, offered moreover by the investments (put in place by the NRRP) to accelerate the achievement of the ambitious global[2] and European objectives to 2030 and 2050 (United Nations, 2015; European Commission, 2019), impose the urgency of new reflections. In this phase of change, the agrarian landscape stands out as one of the main protagonists and the role of architecture, as the person responsible for the processes of land transformation, is therefore crucial.

The article initially sets out to reflect on the formal relationship between agrarian mosaic and architectural forms to understand how these two worlds, only apparently distant from each other, are instead formally united by the same compositional rules. It then moves on to analyse the specific relationship between agrarian vegetation and energy landscape elements in light of the upcoming design opportunities for rural areas. Today we can learn from the design experiments conducted in the past which, although not always positively inserted in the process of constructing the agrarian landscape, offer us the opportunity to analyse certain principles. These principles, together

Fig. 1 | Wind turbines, Tehachapi, California (credit: A. MacLean, 1991).

with other more recent examples, are capable of guiding research into the form problems of future agricultural territories, which must be guided by a conscious relationship between built forms and vegetal forms.

Nature or artifice? | The redefinition of the relationship between architecture and agriculture undoubtedly holds a prominent position among the emerging themes within the contemporary architectural and urban planning debate. The questions left unresolved are not few, and for this reason, the subject has been at the centre of two very recent exhibitions held between 2019 and 2020: Architecture and Agriculture – Taking the Country's Side curated by Sébastien Marot (2019) as part of the Lisbon Architecture Triennale, and the highly anticipated and much-discussed Countryside, The Future, curated by AMO and Rem Koolhaas (2020), held at the Guggenheim Museum in New York. This renewed need for the countryside is quite frightening because of the rapidity with which transformations are taking place within the agrarian landscape. A world that had maintained a slow pace with progressive changes becomes part of a frenetic world that necessarily needs new services, roads, and the cutting down of hedges and trees to facilitate agricultural mechanisation (Bonora, 2015).

Agricultural vegetation and buildings are both logical constructions placed on the land by rules dictated by man. This condition leads us to distinguish nature from agriculture and instead, on a formal level, to associate the latter with architecture. Where the hand of man is not present, nature appears irregular and disordered, while where man has left his mark, nature seems to be subject to a regular order or geometric pattern. The agrarian landscape embodies this condition as the parallel furrows of crops, the straight lines of roads and the regular cadence of plantations replace the irregular tracks of uncultivated woods or the winding paths found on stream beds (Pagano, 1938; Fig. 2). As Pagano makes clear, the agricultural landscape is a strongly structured territory both morphologically and functionally; its 'form' is built on dimensions and geometries that are repeated according to a precise principle.

Precisely because of its characteristics – orientation, size, position, the relationship between the parts – the layout of the countryside must be considered analogous to that of architecture. On the other hand, Carlo Cattaneo (1845) recalls that in the German language the art of building and the art of cultivating are referred to under the same word. The settler is a builder (Bauer) and for this reason, the term agriculture (Ackerbau) is closer to construction than cultivation. According to Cattaneo, people must 'build' fields like cities. The distribution of crops, the planting of fruit trees, water courses and the geometry of fields are artificial products of human labour. It supports but, more often, transforms the spontaneous order of nature to the point of determining themselves the form and, even more, the entire scene of the agrarian landscape, just as an architecture does. In agricultural territories, row crops constitute the fundamental texture of these landscapes. They reveal and regulate both the shape and size of agricultural plots. It is not only a problem related to agriculture or production, but is also a problem related to agrarian structure, since the rows are as if they were erecting a permanent architecture (Desplanques, 1959). Countryside and built-up areas are not unrelated or even contradictory to each other but are both parts of a transformation driven by a common denominator.

Roots and stratifications | The history of the city and architecture is intimately linked to that of productive territories; it is a co-evolution that occurred during the Neolithic

Fig. 2 | Agricultural fields and built adapt to the natural course of the Rio Grande River, Los Ebanos County (credit: J. Begley, 2016).

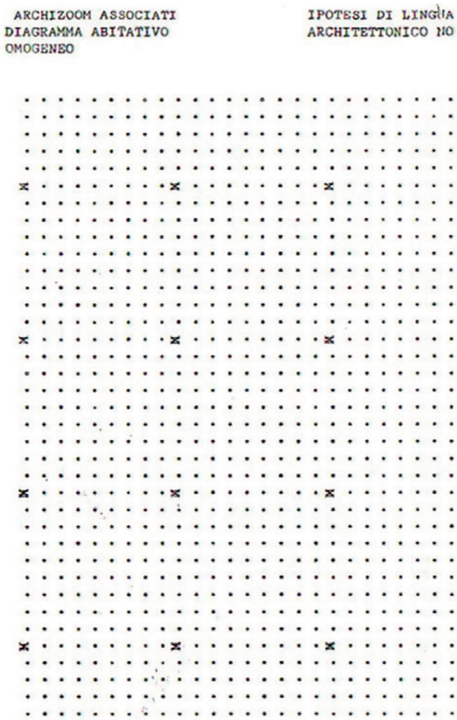


Fig. 3 | Centuriation still evident in the Padovan territory (source: Google Earth, 2021).

Fig. 4 | The grid system that still defines most of the American landscape (source: Instagram account @the.jefferson.grid).

Fig. 5 | Homogeneous living diagram: hypothesis of non-figurative architectural language (credit: Archizoom Associati, 1969).

or First Agricultural Revolution. Sébastien Marot (2019) in Taking the Country's Side – Architecture and Agriculture, a volume that is part of the series of books for the fifth edition of the Lisbon Architecture Triennale, assumes, as many do, that Agriculture and Architecture are twin practices and disciplines; the splitting of which occurred mainly with the rural exodus caused by the Industrial Revolution, only two centuries ago. An extraordinary phenomenon that immediately makes one understand the link between these two worlds is the phenomenon of the Roman centuriation where the composition of the rural and urban terrain is the same. The form, the techniques, the hierarchy between the elements and the orientation coincide to such an extent that between the centuriation of the countryside and the layout of the castrum there is no solution of continuity (Grassi, 1980). This type of organisation of the agrarian territory and then also of the foundation of the new colonial cities, which the Romans introduced at the time of the Republic and then of the Empire to organise the territories of conquest, is the sign of a long period of history that has come down. Today it is still perfectly recognisable in certain parts of Italy (Fig. 3).

The experience of the Romans would later also inspire the visionary Thomas Jefferson, who through the Land Ordinance of 1785, subdivided the American territory into perfectly square or rectangular miles. Both vegetation and buildings were grafted together (United States, 1785; Fig. 4). Similarly, within the avant-garde impulse of the Italian critique of consumerism and capitalism, Archizoom Associati's No-Stop City (1970), to study new forms for the city, will also be governed by a geometric grid that extends infinitely over the territory (Fig. 5). The agrarian landscape is thus complex and ever-evolving and is the result of stratifications on which different writings are progressively accumulated and added to the previous ones (Tosco, 2012).

The rural landscape project | To be able to protect the rural landscape and its history and to ensure the coexistence and function between the different stratifications, past and future, the rural landscape project becomes fundamental. Analysing, describing, breaking down and evaluating the various phenomena affecting the agricultural landscape, often in an unclear and contradictory manner, becomes more indispensable than ever today to identify the right tools for a possible rural landscape project. To do this, it becomes necessary to understand the entire system of connections and relations (spatial, historical, functional, formal) of which a project is part, to safeguard the quality of the entire system into which it is then grafted. The agrarian landscape is a field of investigation that has been particularly investigated by geography; Gambi (1973), Turri (2002), Sestini (1963) and Valussi (1968) are just some of the names on the Italian scene that have dealt with the rural territory. The role of this discipline in the study of the forms and characteristics of the landscape is truly remarkable, but geography limits itself to describing and giving definitions of the constituent elements of the landscape because it does not have the tools to then be able to develop a real project. A task that falls instead to the discipline of Architecture.

Fig. 6 | Lower 'Casone' of Brenta, near Padua (source: Pagano and Daniel, 1936).

Fig. 7 | Agricultural geometrization (source: Edilizia Moderna, n. 87-88, 1965, p. 58).

Since the beginning of the 20th century, the debate around the morphological problems arising from the phenomena of city dispersion has given rise to a period of strong experimentation based on the possibility of building new parts of cities immersed in the agrarian landscape. Often, however, these activities and proposals for integration have been focused above all on the functional and technical-constructive solutions of individual buildings, to the detriment of open space, especially in rural contexts where the space of connection between buildings, made up of vegetation and other elements – farmyards, open spaces, vegetable gardens, crops, fences, the irrigation system, the energy system – constitutes the structuring part of the rural settlement.

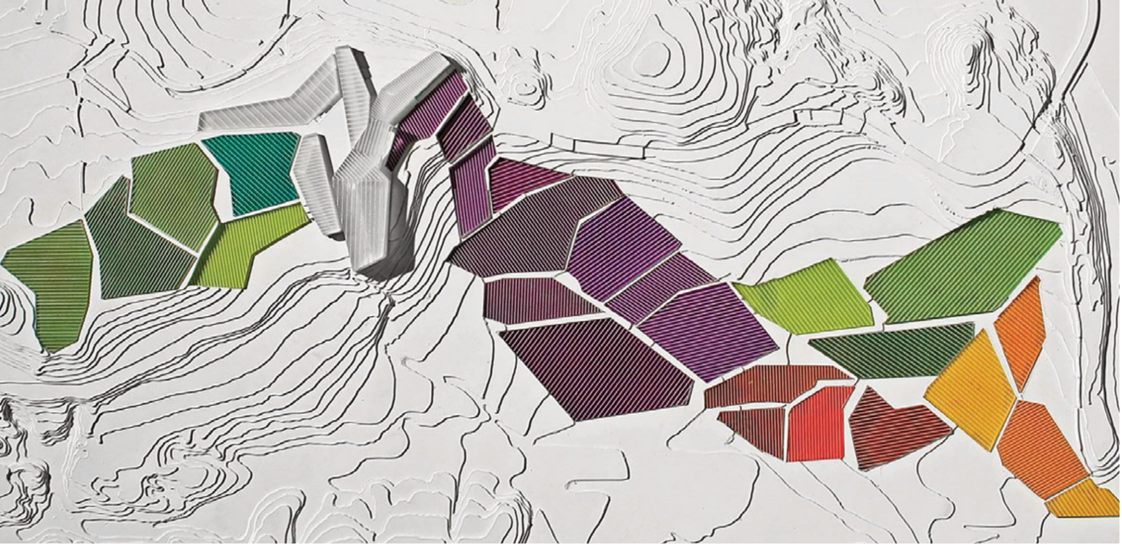
In the 1930s, for example, Giuseppe Pagano highlighted the link between rural architecture and rationalism, but his attention was only focused on individual rural houses, never mentioning the relationship with the surrounding vegetation in his catalogue Architettura Rurale Italiana (Pagano and Daniel, 1938; Fig. 6). Instead, for the historical context of those years, Alberto Sartoris' considerations (1944) are important. In his book entitled Introduction to Modern Architecture, Sartoris dedicates three chapters to the issues of the city-countryside relationship. In the first of these chapters (Organizzare le campagne), like Pagano, he limits himself to talking about the country house, which must be designed and built according to the principles of rational architecture, making use of modern construction means.The focus is always on buildings that reflect the spirit of the contemporary architectural movement. In the chapter 'La città deve andare verso la campagna', the author begins to reflect on the arrangement of sites in which to locate the building, thus beginning to pose the problem of the intimate union between nature and geometry and how vegetation becomes part of the orthogonal volumes of modern architecture. It is also affirmed that urbanism, through a return to the beauty of the earth, is attempting to organise nature in the same way as modern houses are equipped.

Italian architecture's interest in the landscape, especially in landscape design, was renewed from the 1960s onwards, thanks to the theoretical foundations of certain contemporary orientations in the discipline of architecture. Particularly important were the reflections that emerged from some of the articles in number 87-88 of the magazine Edilizia Moderna (1965), entitled 'La Forma del Territorio' (lit. The Shape of the Territory). These reflections were dedicated to a list of problems in the work of architects related to environmental problems on all dimensional scales, «The 'form' is no longer the perceptible aspect of the work, but a structural problem, which has to do with the aspect of relations between the parts of a system. The 'shape' of the territory observed through aerial photographs shows that the interpretative criterion does not vary if the transformations have been carried out by nature or by man: where they establish descriptive formal sets, the presence of the project can be recognized» (Tesoriere, 2020, p. 49; Fig. 7).

Among the articles on the subject, Norberg-Schulz (1966) expounds on the need to analyse the formal properties of both landscape and architecture in detail to be able to work on the landscape without destroying it. This can only be done by using the same concepts when defining forms of landscape and forms of architecture. The 87-88 issue of the magazine Edilizia Moderna (1965) developed a debate that certainly produced some important conceptual tools, but in later years, these theories were reduced and trivialised. In such studies, however, the agrarian mosaic was rarely taken into consideration by architects as a built element on a par with buildings. Some valuable insights were left unfulfilled concerning their potential, such as Wright' Broadacre City (2013) or Giuseppe Samonà's City in Extension (1976).

Even in the contemporary context, looking for projects, in which the building is conceived in perfect communion with the agrarian forms, is by no means easy or obvious. A remarkable example of integration between the two worlds, where the design process of the final work is perfectly legible, is the Royal Wine Centre by Nieto Sobejano Arquitectos (Fig. 8). The project that was not realised but won first prize in the Rioja Wine Museum Competition (Spain, 2005), is a true landscape intervention where the geometry of the building and vineyards is conceived with the same design rules, so becoming a single design (Fig. 9).

The Royal Wine Centre is as much landscape as building. The design evokes geometric laws that were intrinsic to this vineyard-rich landscape. The terraced surfaces of the buildings adapt to the irregularities of the area to naturally define the different elements of the project, which consists of five bodies, forming areas for exhibitions, training, hotel and restaurant services, and parking. The architects imagined how the agricultural characteristics could be the suggestion to start a project in which the proposed spaces are not limited to a specific shape or size – as they are expandable or reducible vineyards – but become the expression of a geometric rule that can eventually change its dimensions or positions to expand or concentrate new areas in the future. The building thus represents the encounter between topographical landscape and archi-



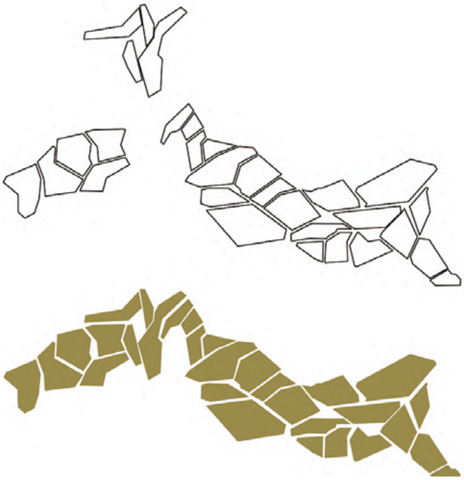


Fig. 8 | The Rioja Wine Centre project in Logroño, Spain (credit: Nieto Sobejano Arquitectos, 2005-06).

Fig. 9 | Outline of the Rioja Wine Centre: the same geometric rule governs the shape of the building and vineyards (author's elaboration, 2022).

tecture. Finally, giving architectural form to the countryside is a very difficult task and thinking of it as a part of the settlement is certainly one of the most difficult tasks for an architect today (Gregotti, 2003).

The new risks | Until the middle of the last century, global ecosystem balances and the balance between species held. Furthermore, biodiversity managed to ensure that cycles and circularity work properly. The 1950s were the years of great acceleration when man began to raise the levels of aggression against natural systems to intolerable levels. After a long process of cultural contrasts, where the countryside suffered the unstoppable advance of the city, we are now in a phase of change. Compared to the trend that occurred in the 1950s-1960s, characterised by the exodus from the countryside to the cities, a slow reversal is taking place: the rural exodus is beginning to be replaced by the urban exodus. The phenomenon has been greatly accelerated by the recent pandemic, which has contributed to spreading this 'fashion' of a quieter and healthier life accompanied by less frenetic rhythms, leading to a reappraisal of the pros of rural life, as opposed to the frenetic and stressful urban life. A realisation that was known even before, but that Covid-19 has crystallised.

The difference concerning the past is that the rural territory, today more rapidly than in the city, is undergoing considerable changes due to both environmental problems and ever faster technological advancement. The dynamics of economic development together with the maximum exploitation of agricultural productivity have come at the expense of the preservation of fundamentally important elements within the rural territory, such as hedges or groves, which contributed to the formation of an agrosystem. The richness provided by these elements not only contributes to shaping the construction and perception of the landscape but also functions as an ecological bridge, creating a balance of biodiversity and contributing significantly to the decrease in the vulnerability of the landscape. The extension of monoculture and the consequent cancellation of the cultivation warps have distorted and trivialised the landscape textures. As a result, the countryside no longer seems to correspond to the idealised icon of a pleasant space, due to the infrastructures that mutilate the ecological networks, made ugly by warehouses, rows of small villas and megastores, flattened by the logic of agroindustry and victim of monoculture and its endless fields (Bonora, 2015). Paola Bonora makes it very clear how often the agrarian landscape is both victim and executioner of its disfigurement.

Putting pressure on rural landscapes and pushing architecture to new urgent reflections, today the new challenges are also proposed by the NextGenerationEU (European Commission, 2020) or the PNRR (Italian Republic, 2021), which aim to achieve 'carbon neutrality' in 30 years. Coal, along with oil, is one of the most widely used fossil fuels and the most polluting and climate-changing, and it is no coincidence that a large part of the CO_2 that infests the air is caused precisely by the disproportionate use of coal. When we talk about energy transition, we inevitably also talk about landscape transition. The use of renewable sources is like bringing the energy landscape

Fig. 10 | Garzweiler surface mine, Germany (credit: A. Mueseler, 2019).

Fig. 11 | Photovoltaic system in Troia (credit: EOS, 2020).

closer to our culture, also because traditional fossil fuels can often be associated with landscapes that not only do not convince us but also do not belong to us. For a series of reasons, they cannot be realised in our territory, because not only they are dangerous but also need specific infrastructures (in Italy there is only one active coal mine, and it is in Sardinia). So it is in neighbouring Germany, whenever a new coal mine must be opened, villages and hectares of farmland are easily destroyed to make room for the mines (Ulivieri, 2020; Fig. 10). Resorting to renewable energies is therefore urgent and necessary, but how will wind and photovoltaic plants, which are the two technologies that will contribute most to the increase in renewable capacity, be placed in the landscape?

Landscapes of the near future. Photovoltaic 'fields'? | The National Recovery and Resilience Plan – with the investments envisaged for the 'Protection and enhancement of architecture and the rural landscape' in Mission 1, and the conspicuous investments made available for the Green Revolution and Ecological Transition envisaged instead in Mission 2 – aims to accelerate the ecological transition in Italy. It moves towards complete climate neutrality, cutting climate-changing emissions, through energy efficiency, the promotion of renewable energies, the circular economy and the protection of natural and agricultural ecosystems and biodiversity. People should be aware that after roofs – covered with photovoltaic panels that often mortify architecture itself – landfills and disused industrial areas, shovels and panels will have to spread to the countryside as well. The report on land consumption 2021 by the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA, 2021) revealed that 179 hectares of land were 'consumed' in 2020 for the installation of new ground-mounted photovoltaic systems. In particular, the second municipality for land consumption in 2020 is Troia (Foggia, Italy), with 66 hectares of increase. The origin of this land consumption is due to the expansion of the areas destined for the installation of ground-mounted photovoltaic panels, on previously agricultural areas (Fig. 11). It is therefore a landscape problem. The landscape has often been considered an 'empty' space at the disposal of human needs. It is not only an aesthetic problem and due to its complexity, cannot be underestimated and left to the choices of industries, the desperation of farmers in search of subsidies and the inability of administrators (Silvestrini, 2022).

The risk of accelerating these challenges is certainly that of not having an overall vision that holds together the agrarian territories' project, landscape, history, nature, and culture. The 'time' factor is therefore among the first critical issues to be considered. Since these investments, which also translate into new infrastructures to produce those renewable energies that will fall right on the landscape, must be completed by 2026, experimentation is necessary to obtain effective results. Also, necessary research activities are needed, which – as those involved in agriculture know – take years, to try not to fall into a false ecologism – concealed behind slogans such as wind 'parks', solar 'farms', photovoltaic 'fields' – that only leads to the contamination of the landscape.

Fig. 12 | Gujarat Solar Park, India; Plant near Viterbo, Italy; Gemasolar, Andalusia, Spain; Solar power plant in Ouarzazate, Morocco (author's elaboration, 2022).

Fig. 13 | Agrivoltaic systems (credit: NETF Milano Srls, 2022).

Fig. 14 | A rendering of the channel section (credit: Solar Aquagrid LLC, 2021).

Reasoned choices must be made in the identification of suitable areas where wind and photovoltaic plants will be located, as these are elements whose harmonious inclusion in the landscape requires considerable design sensitivity. Also, because renewable energy plants generally have a much lower production capacity per unit area than traditional fossil fuel plants, so their diffusion will affect much larger areas of land and therefore landscape (Magoni, 2013).

The impact of photovoltaic plants on the landscape can easily be seen by looking at the landscape from Google Earth (Fig. 12). Renewable energy plants are certainly an opportunity to be seized, but the risk of a serious loss of biodiversity and speculation of agricultural soils is equally high. What is needed, therefore, is a systemic vision of the landscape that corresponds to the logic of both ecological-landscape balance and sustainable energy exploitation, which can only be dictated by rigorous planning (Barbera, 2022).

It is incumbent on architects to study at this stage the different forms of compatibility between energy installations and the formal structures of the landscape that embrace buildings, geography, saltus and ager at the same time. We cannot risk once again neglecting the landscape value of agrarian landscapes, which does not mean imposing either a conservative or a technicalistic approach (Magoni, 2013), but accepting that the landscape implies transformation. Therefore, it must be designed bearing in mind that all the elements that belong to it – vineyards, olive groves, buildings, wind turbines, photovoltaic panels, watercourses – must be part of a unitary design.

Considering the complexity of a unitary design is fundamental today. If we do not want to fall into the errors of the past since everything that will be ‘thrown’ onto the landscape without a design logic will contribute to the perception of ‘forms’ that will characterise that place for a significant time. Transformation is inherent in the very concept of landscape, and therefore also of energy landscapes. Let us think of the windmills that have characterised the landscapes of Europe and other continents for many centuries, and which are an example of an artefact in harmony with nature that can utilise a renewable resource. There are many proposals underway, such as the recent spread of agro-voltaics (Fig. 13).

Are there alternatives? Yes, but largely yet to be defined and the timeframe for experimentation is very short. California, for example, is testing its first solar channels. The Solar AquaGrid research study, commissioned by the Citizen Group and conducted by researchers at the University of California, Merced, and UC Santa Cruz, revealed that numerous advantages can be gained by installing solar panels on open water channels compared to traditional ground-mounted solar systems. In the paper entitled ‘Energy and water co-benefits from covering canals with solar panels’, published in Nature Sustainability, the American scientists tested that solar panels shield canals from direct sunlight, helping to mitigate evaporation and the growth of aquatic weeds, reducing water loss, generating solar energy, and without occupying arable land (McKuin et alii, 2021; Fig. 14).

Concluding remarks | The landscape is changing and will inevitably undergo major formal transformations, in addition to all the possible environmental hazards, e.g., related to soil erosion. What we call ‘landscape’ is certainly a process of adaptation between the environment and man and results modifiable over time. It is essential to accept that the future landscape will be different from the current one and that new challenges may be solved through a new co-evolution between man and the environment (Scandurra, 2022).

The change taking place certainly cannot be assessed only from an optimistic purely technical-energy point of view. To avoid uncontrolled growth of photovoltaic panel ‘fields’ or wind ‘parks’ – which could become part of a new ideal additional chapter to Emilio Sereni’s Storia del Paesaggio Agrario Italiano (1961) – and in the hope that what such projects will bring will not further contribute, as has happened in the past, to the gradual disappearance of beautiful Italian landscapes in favour of ungainly and dishevelled forms (Bonora, 2015), designers, planners, agronomists and legislators will have to tackle the problem together, taking into account, on a case-by-case basis, the impact of each intervention. It is necessary to adopt coherent design criteria and a unified project design that considers the positioning of the various components on the landscape and verifies that the new project is carried out with respect for environmental, ecological, and pre-existing values. It is also necessary to decipher the landscape, highlighting how relations with the energy issue have contributed to shaping it over time (Briffaud and Ferraraio, 2015).

The realisation of new interventions is therefore an opportunity to reflect on new opportunities for enhancing agricultural landscapes through the proposal of new elements as an integral part of the landscape in which they are inserted. It becomes fundamental that the new formal proposal affects not only the productivity of an area, but also the aesthetic quality of its landscape and the quality of life of the people living there (Magoni, 2013). Fully understanding the co-evolution of landscape and energy use becomes essential to minimise the impact of the new insertion and to ensure that the energy transition is guided by a unified landscape design. The timeframe is long in agriculture and the spatial response still uncertain.

Notes

1) The Secretary-General’s video message at the press conference Launch of the IPCC report 28/02/2022 can be found at: media.un.org/en/asset/k1x/k1xcijxjhp [Accessed 20 August 2022].

2) More information on the Sustainable Development Goals (SDGs) can be found at: sdgs.un.org/goals [Accessed 20 August 2022].

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NATURE AND HERITAGE
Approaches to transform urbanised water landscapes

Giulia Luciani

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ABSTRACT
Each design project on the water landscape requires the acquisition of a specific behaviour towards nature: clarifying the requirements of the observed attitudes is fundamental to considering which value system should be shared in the ecological conversion of the urbanised environment. Among the most used approaches, the contrast between an anthropocentric and ecocentric debate shows the existence of a crippling dichotomy between nature and culture, that some environment-oriented approaches try to mend and overcome. In the experiments aimed at this objective, heritage has a crucial role in the territory project, even with the wide range of interpretations and practices, as it emerges from the analysis of three case studies: the new paradigms originated in the Netherlands in river and heritage management, the experience of the Landscape Observatory of Catalonia catalogues, and the Territorialist School's concept of territorial heritage.

KEYWORDS
landscape, territory, urbanised environment, nature, heritage

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Complexity, dynamism and plurality have always characterised water landscapes, especially those where human presence has added to the exceptional ecological wealth the settling of anthropic legacies while increasing its vulnerability to natural agents. Today we witness a ferment of ideas to reshape the relationship between urbanisation and the natural environment, fostered by a growing awareness of global and local issues. Although the need for a new attitude toward nature is constantly reminded, each strategic vision adopts its own approach, often contrasting with alternative visions that also share similar goals. For instance, it is clear in the contrast between a radical ecologism and a compensatory and mitigating approach. The concept of sustainability, as the concept of nature, is often considered as starting data.

The aim is to explicit the requirements of different attitudes toward environmental transformation to stimulate considerations on which system of values to share to address not only environmental but also urban, social and cultural problems. We will describe a framework of approaches to the ecological conversion of the urbanised environment, particularly referring to, but not limited to, water contexts. It will highlight the different ways to intend the relationship between human beings and nature, investigating the possibility for the heritage to have a key role in reconciliation strategies between human intervention and the natural environment. In particular, we will find experiences and theories aimed to truly overcome that dichotomy between nature and culture that seems to be the foundation of the modern era.

In the first part, we will examine different types of approaches, classifying them within three ideal categories; in the second section we will deepen the third category, having the most interesting insights on overcoming the nature-culture dichotomy; finally, we will deal with the heritage subject through three case studies: the new paradigms originated in the Netherlands on river and heritage management, the experience of the Landscape Observatory of Catalonia with landscape catalogues, and the Territorialist School's concept of territorial heritage. In the last part, we will deal with critical issues and future research trends.

Three Conceptual Approaches | Every project on water lines concerns a series of problems and subjects that need to be dealt with in a project plan. However, before that, redefining the relationship of the urban landscape with water means reinterpreting reality with a naturality that can never be entirely eliminated. Ventura Pujolar, Ribas Palom and Saurí Pujol (2002) attribute the practical and theoretical approaches to the management of rivers to two opposite models, anthropocentric and ecocentric. The first one considers the river as a source of natural resources, and the second refers to an ideal natural status, before human intervention. To the two models correspond different concepts of the relationship between nature and society, considered by both as opposite poles of a dualism. While the anthropocentric view aims to increase the material well-being of society, the ecocentric one aims to reach a natural balance. Different disciplines refer to them: water quality and quantity control, and river ecology.

They present the river on the one hand as a controlled object without a context, and on the other, as the subject to a return to an original – but still hypothetical – place and time. Both views, when some problems arise – such as an extreme weather event – identify the cause in the opposite view and propose as a solution the radicalisation of their conceptual and scientific principles. According to the authors, the inflexible contrast blocks the solution of conflicts that would be possible by adopting an 'environmental' model, therefore considering a dialogue in the dualism between a complementary 'anthropic view' and an 'ecosystemic view'.

It can be noted a similarity with the three attitudes towards the territory described in the same years by Magnaghi (2001): dissipative, typical of industrial modernity, of which ecomodernism is its most up-to-date version; conservative, mostly typical of ecological culture; a third attitude, finally, bases the development on the enhancement of the heritage, in the global meaning of interaction between environmental, territorial and urban systems, society and local cultures. Although the two models are clearly not superimposable, they share the idea of an insufficiency of both dominant attitudes in the contemporary culture on the needs established by the cultural and environmental crisis and try to trace a third path with an integrative and interactive method. With the aim to find approaches similar to this third way of conceiving the environment, it was attempted to attribute to the three models some of the main trends in project and nature. Table 1 summarises and confronts the main characteristics of the two models as described by the authors, and those of the environmental model derived from the examples given in this paper.

Concerning anthropocentrism, there is a category of approaches and considerations denoted by the formula 'sustainable management'. Sustainable management embraces the institutional and globalised view of the Anthropocene (Barca, 2020), follows development and progress objectives and considers nature as a resource. An asset to be handled wisely in the long term and using the best available technology, on which we rely to turn the tide of environmental deterioration, but especially of climate change (Pavia, 2019). Although the list of usable resources includes nature-based solutions and ecosystem-based approaches, grey solutions are still the most used (UN Water, 2020). It adopts definitions and tools such as Natural Capital and Ecosystem Services to promote the sustainable nature management practice. The ecosystem services concept is increasingly diffusing but shows problems and inconsistencies, including considering nature only as a commodity with instrumental and exchangeable values, placing it fully within the logic of exploitation that it wants to contrast (Poli, 2020).

At the opposite pole, there are biophilic approaches, which consider nature and its processes as the main reference to design the built environment as a human biological need. The main focus is to reestablish the connections between the human and natural spheres, moving the first towards the second. The 'sense of place', of which the cultural dimension is a part, has mostly this reconnection function – only partially similar to the 'place consciousness' of the territorialist approach mentioned below because it

Model	Anthropocentric	Ecocentric	Environmental
Society-nature relationship	Demand and consumption	Preservation and restoration	Democratic care and enhancement
Aim	Increase of material wellbeing	Natural balance	Natural and human balance
Reference	Fluxes	Pristine nature	Human environment
Scientific discipline	Water regulation (quality and quantity forecast and control)	River ecology (natural values preservation)	Territory and landscape sciences (human and natural values formation)
Time	Linear progress	Retrospective	Longue durée
Space	Anonymous	A (new) previous place	Identitarian, historic, relational place
Social aspects of the river	Economic-rational	Identitarian-emotional	Relational
Management model	Contractual	Balance between minimizing human impact and allowing for contemplation	Holistic
Origin of conflicts	Ecocentric model	Anthropocentric model	Uncompromizing opposition of models

Tab. 1 | Main characteristics of the anthropocentric, ecocentric and environmental models.

is mostly linked to an aesthetic-perceptual sphere. It favours a regenerative-based design, capable of self-sustaining because it uses models of energy flows and cyclic materials, and makes extensive use of nature-based solutions, leaving nature 'letting nature do the work' (Lyle, 1994).

The Environmental Approach | One of the distinctive features of the third approach is the research of a dialogical reconstruction of inflexible dualisms. On the other hand, the attempt to overcome the dichotomy between nature and culture characterising the modern era (Latour, 2018) is a standard subject nowadays. In environmental ethics, the discussion on the tension between anthropocentric and non-anthropocentric ethical systems has been fundamental. It was enhanced by some points of view, such as ecofeminism, whose main contribution is a radical critique of all centre-based systems. The trend, however, was to take on one polarity or the other without being able to address the dilemma between social and environmental concerns, and thus the nature-culture paradox (Proctor, 1998).

This is a crucial problem for some authors that link it productively to the contemporary urban condition and its contradictions. Augustin Berque (2016) questions why

Fig. 1 | Parco Regionale dell'Appia Antica, for which V. Calzolari coordinates since 1973 a project proposal, is an example of the unbreakable integration between history and nature, that characterises the landscape of the Roman area (credit: Lorenza Campanella, 2016).

the past generations – which did not have the concept of landscape – have left admirable landscapes, while the current one, which has made high-end considerations on this subject, in practice, is destroying landscapes and territories. At the base of the paradox, there would be the Modern Western Classical Paradigm that, by relegating nature to a neutral object in a universe independent from the subject, would produce a 'decosmicisation' of the human environment. The idea of decosmicisation can be found also in the considerations made by Anna Marson (2008). According to her, this process – eliminating the sense of sacrality of the earth and the relationships between human microcosm and macrocosm – contributes to deteriorating the relationship with the environment. It is the abstraction of the modern subject from its own 'milieu' that destroys the conditions of its permanence on Earth. According to Françoise Choay (2008), the result of the abstraction concerning the organization of the space consists of a series of deprivations, expressed through the neologisms: dedifferentiation, decorporealisation, dememorisation, and semantic decomplexification. The way to 'recosmise' human existence, according to Berque, goes through recognising what he names 'médiance': while the concept of environment reproduces an object foreign to the human being, the médiance conveys the idea that we are not only part of the environment, but that the environment is also part and parcel of our being.

Following these considerations, we notice in the 'environmental' approaches the constant of seeing the natural context not as absolute, but as co-evolved, so that its anthropic component and the transformations it originates are its part and parcel. The idea of an environmentalism joining landscape, environmental and anthropic matrixes was already written by Elena Croce, founder of Italia Nostra and protagonist of environmental battles since the 1950s, whose influence has also inspired the approach of the Fondo Ambiente Italiano. The defence of the territory from chemical and urbanistic aggressions, in old towns and landscapes, joins the protection of the reasons for life and humanity embodied in history and nature (Fava and Caputi, 2018). The close bond between history and nature appears in the design perspective by Vittoria Calzolari, also linked to Italia Nostra, and probably influenced by the Roman landscape, to which she has dedicated much of her work (Fig. 1). According to her idea, materiality and historicity of the territory are always associated: historic and environmental patterns, especially hydrographical patterns, are conceived as parts of a system where tight interconnections take on a structural aspect (Calzolari, 1999).

In the contemporary scene, the idea of nature and culture considered as unicum is progressively cementing in the field of heritage conservation, and in particular in the so-called cultural landscape protection, in which the contributions of the research lines followed by the two UNESCO branches converge. It is increasingly acknowledged that the biological diversity is often paired with great cultural richness and variety, since biodiversity and other natural values are not menaced, as was believed for a long time, but are boosted and enhanced by the care of people (Brown, Mitchell and Beresford, 2005). At the same time, it emerges the need to overcome the protectionism paradigm, and consequently a synergy between conservation, management and planning.

Fig. 2 | The works for the project Room for the River along the Reno-Maas delta (processing by the Author).

The Role of Heritage | The fact that environmental approaches have been established in these fields seems to suggest the importance of the (also) cultural heritage, which might prove to be a crucial key for urbanised water landscapes, rich in stratifications of civilisations and ecosystems. Is there a virtuous relationship between heritage and the 'environmental' transformation of the territory? Can it have a role in closing back the gap between nature and culture at the design level? To attempt an answer, we analysed three case studies belonging to the category of environmental approaches.

In the Netherlands, since the beginning of the 2000s, a new approach to nature project entwined with a new approach to water heritage. The cultural ferment as a response to the disruption after Hurricane Katrina marked a conceptual transition from the old model 'drain, dredge, reclaim', to a new one, whose motto is 'working together with water' (Meyer, Nijhuis and Bobbink, 2010). In the area of Rotterdam, from 2005 to 2015, a bank and canal redesign, and flood control strategies, in general, were experimented, aimed at 'making space for the river' (Figg. 2, 3). The second objective is spatial quality, intended as a balance between hydraulic efficiency, ecological robustness, and cultural and aesthetic sense. The attitude towards history is intentionally selective, unlike the procedures adopted for UNESCO sites, where the past chooses the present and not vice versa. The cultural and aesthetic factors are fundamental for the residents to accept the change. We see a redefinition of the relationship between humans and water – that is the environment – where dichotomies and strict separations are no longer considered, but a logic of coexistence is introduced. In the past, it was about implementing human values to nature, now about making the natural element contribute to defining the value system of the human environment. Continuity and change stop being two opposing categories and become one premise of the other, becoming side-by-side rather than opposing elements.

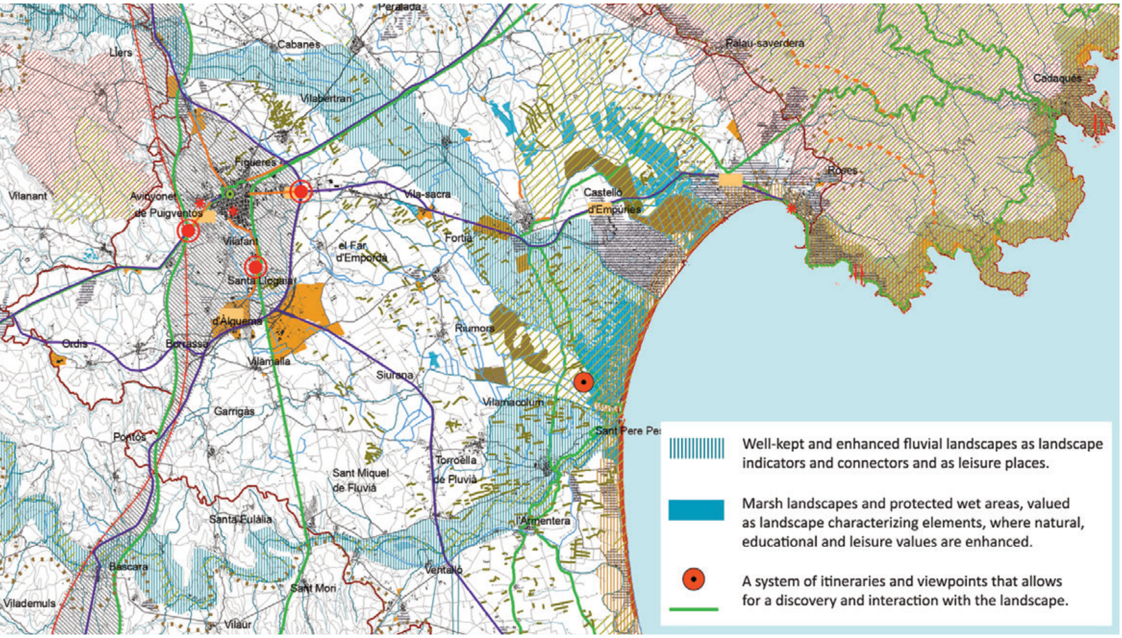
In this way to imagine continuity and change, we can see the similarity to another change happening in the management and conservation of the wide heritage of hydraulic systems of local tradition. There is a debate between the promoters of a total change – who emphasise the traditionally innovative nature of water management strategies and technical solutions – and the supporters of the conservation of historic structures. But, a national program has been implemented since 1999 for the integration of material heritage into a new spatial territory plan with a dynamic approach, promoting the creative reuse of the existing heritage or the creation of new buildings based on the reinterpretation of historicised approaches (Hein, 2020). In this case, heritage is made of material structures, in their physical presence and their interaction and integration with the landscape, without which they would be unintelligible; and intangible structures, including narratives that inform collective identity, such as the resourcefulness and creativity in the relationship with water.

The Landscape Observatory of Catalonia was born in 2005, implementing the European Landscape Convention. Its main activity is creating landscape catalogues (Fig.

Fig. 3 | View of Rotterdam within the Maas river delta (source: Emma/stock.adobe.com/it/).

4). The novelty of catalogues compared to their antecedents, atlases, is the role of tools to guide the transformation (including SWOT analysis, quality objectives, guidelines, measures and action proposals) and the close integration with plan tools. Concerning the method, the Observatory has an integrated vision of natural and cultural aspects of the landscape, in which it finds and analyses a wide range of values (Nogué and Sala, 2008). The landscape is structured as an operational tool, a cross-disciplinary mechanism integrating physical, cultural and spiritual aspects, aiming to direct the territorial transformation according to the intrinsic characteristics and aspirations of the natural and human environment. Mostly about the subject of water, thinking about the landscape means interacting with the wide range of uses and actors involved. In 2016, the Observatory has dedicated a publication to the relationship between landscape, water and heritage, where it was underlined that water is both a structural and transversal element for the landscape, and speaking about water is 'almost like speaking about landscape' (Nogué, Puigbert and Bretcha, 2016).

According to the idea of the Observatory, the concepts of heritage and landscape ultimately tend to converge, while the main difference remains at the disciplinary level



(Fairclough, 2016). Both tend to be considered less as objects and more as processes, referring to complex sets of objects, concepts and ideas, that gain value since they are inherited from past generations and are subject to different menaces, dealt with a series of protection, reuse and transformation actions. Together, heritage and landscape provide a holistic framework to deal with global problems and their impact on people's lives. Landscape is common ground – both in literal and figurative sense – where to meet the community, that is the main reference point and that has in it an important component of spatial, individual and collective identities.

The approach developed from the 1990s by the Territorialist School, which then converged in the Territorialist Society, elaborated a project to return to the physical and cultural connection to the territory, within bioregionalist planning. As a project of ecological conversion tool, it aims to preserve the human environment instead of the protection of nature and entrusts territorial communities with the task to rebuild rules, behaviours, cultures and ecological techniques of living and production according to bottom-up process. To implement a virtuous cycle should be created: thanks to the growth of place consciousness it produces a re-identification with the territorial heritage. According to Magnaghi (2020), this should be reinterpreted with the médiance of a local society that recognises it, cares for it, and treats it to produce lasting wealth.

The territorial heritage is neither a Natural Heritage used as a reference by the approaches based on ecosystem services nor a universal heritage such as UNESCO World Heritage. According to Magnaghi (2020), it is a common asset with use and existence

Fig. 5 | Processing of a detail of the territorial heritage map from the Landscape Plan of the Tuscany Region and an excerpt from the legend (source: PIT Toscana, Scheda ambito di paesaggio 'Bassa Maremma e ripiani tufacei').

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Fig. 4 | Processing of detail of quality landscape objectives of the Landscape Catalogue of the Province of Girona and an excerpt from the legend (source: Catàleg de paisatge de les comarques Gironines, Mapa 12 – Objectius de qualitat paisatgística).

Case study	Netherlands	Territorialist School	Landscape Observatory of Catalunya
Heritage definition	Material structures, considered in their physical consistency and interaction/integration with the landscape, and immaterial structures shaping their values (identity structures and narratives)	Territorial heritage, made of the elements, goods, and environmental/urban/ rural/infrastructural/ landscape systems that shape a region's identity in a material (because of their permanence), perceptual and cultural way	Merges with that of landscape, a process through which people negotiate the relationship between past and future. Set of inherited, valuable, and threatened things/concepts/ ideas, components of space perception and individual and collective identity
Actions on heritage	Preservation, creative reuse	Patrimonialization, enhancement	Cataloguing, objective definition
Roles of heritage	Shape and preserve awareness of the environment and its risks	Shape place consciousness	Maintain and improve life quality
	Strengthen social cohesion in response to extreme events	Reactivate care actions	Integrate disciplines contributing to territorial transformation
	Define collective identity	Grow wealth (not profit but goods, services, employment)	Express the community's aspirations
	Add cultural and aesthetic meaning to spatial quality	Provide basis for self-sustainable local development models	
	Mediate between human activities and landscape		

Tab. 2 | Comparison between approaches and interpretations of heritage.

values, made up of the environmental, urban, rural, infrastructural and landscape elements which contribute, to their historical permanence and in the way they are perceived by the population, to shape the identity of an area from a material, perceptual and cultural point of view (Fig. 5). To define what is to be considered as heritage, and therefore what needs to be well-kept and maintained to be at the core of the project, is incremental and non-universal, to be built collectively by the community and experts. As a consequence, the heritage receives particular attention not only as data but as the heritigization process that leads a community to select and decide what to value the most. These processes constitute a fundamental step to create a project in the community (Poli, 2013).

In Table 2, some aspects of the three experiences are compared. A similarity can be noted between the Territorialist school and the Observatory in using an extended definition of heritage compared to the more specific one in the Dutch case. This contributes to attributing more transformative roles, particularly in the territorialist case, where heritage is an active subject and not only the object of creative operations. Of course, the Dutch particular environment and culture about water and hydraulic structures partially explain the difference from the others. Instead, what emerges is a mediating role between society and the environment, supporting the building of community resilience when facing traumatic events and necessary changes.

Final Considerations | In this paper, we have tried to reason on the possible approaches to the ecological transformation of urbanised water landscapes. We have started from the idea that these places, in particular river deltas, are an insoluble twine of nature and culture, full of priceless biological and heritage assets. We have set a way of reading the methods through which the project of territory deals with the environment through three categories having at their core, one the human material well-being, the other untouched nature, and the third the search for a non-confrontational but mutually enhancing integration. We have deepened some aspects of the third category, noting its capacity to balance unbalances occurring when one polarity prevails over the other in a conflict and imagined how the local heritage can be the key in the transformation process, finding a rich topic still in need to be explored.

Clearly, the approach classification proposed should not be considered valid for every case. Since it is a model, there could be contaminations and overlaps of approaches that rarely correspond exactly to a category specific to the subject, therefore, many other classifications are possible and not every approach can be included. Tracing a pattern is a difficult job, moreover, we are working in a time of cultural turmoil, with a growing number of interpretations of the environmental crisis and scenarios of meaning. This opens up for the human race and other species, present and prefigured hybridisations between the organic world and technologies (Perriccioli, 2021), transhuman and geo-engineering tendencies (Wallach, 2019) that would redefine the terms of human and natural in reference no longer to mutual relations but to the third term of artificial origin.

Moreover, thought schemes and languages have an innate difficulty, where the dichotomy between nature and culture could only be eliminated by using new words, and new concepts, such as the 'collectives' present in Gaia by Bruno Latour (2020). Even the will to label, and set logical boundaries to the 'weird' complexity of the real world, according to some writings, is a symptom of the original violence that separates humans from the rest of the world (Morton, 2016).

However, some key points originating from this point of view can be underlined. The existence of dichotomous patterns makes it difficult to understand relations between cultural and environmental heritage besides the more obvious ones between heritage and society. Many works, also by Institutions point out the importance of heritage in the environmental crisis but are limited mostly to framing it as an endangered object, or as a factor of social cohesion in response to extreme weather events (ICOMOS/ICORP, 2013). Therefore, the need and opportunity to integrate the subject areas stand out, hoped for not only in the context of 'environmental' approaches but also in the research on ecosystem services, for example, whose problems could find a partial solution in the convergence with the research on the landscape (Martin-Ortega et alii, 2015). Along with sectoralism, another tendency to overcome is 'expertism'. A shared design should be favoured, starting from the idea that there is no single valid sustainability scenario for every place, but that the suited solution originates from the context: environmental, biological, human, and social-cultural. Finally, the most important incentive coming from these experiments is to shift from a resistance logic to a project one, aiming to the construcion of a world that reproduces neither an idealised past nor a present without alternatives.

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PLANNING PARALLELS BETWEEN FLOOD RISK MANAGEMENT AND ECOLOGICAL LANDSCAPE DESIGN
The Italian regulatory system and the Po River case study

Lorenzo Tinti, Elena Verzella

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ABSTRACT
The growing instability of river ecosystems in terms of flooding danger requires risk management systems at the territorial level that can reconcile issues like territorial protection, environmental improvement and biodiversity management. This paper explores the need to propose models that relate to the dynamics of river ecosystems rather than forcing rigid, confining infrastructures on them. This paper will analyse the potential of ecological landscape design, nature-based solutions and a case study of the Po River to set out several theoretical assumptions needed to draw up large-scale planning and design strategies, where the use of said instruments takes account of the current climate adaptation and risk reduction needs and also allows enhancing the environmental, economic and cultural value of the territory and the landscape.

KEYWORDS
landscape architecture, ecological design, flood risk management, nature-based solutions, territorial resilience

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Climate change is altering the frequency, intensity and severity of environmental disturbances, resulting in negative effects on the landscape, abrupt changes to ecosystems (Turner et alii, 2020; Lewis and Maslin 2005; Poff, 2002) and serious repercussions on the economic level (Amadio, 2012). One of the most pressing issues is certainly linked to the management of water (Fig. 1). There is broad consensus that flooding risks are increasing in the face of an escalation in extreme events (Merz et alii, 2010; Ming et alii, 2021) and that the impact at territorial level is not insignificant (Meng, Dabrowski and Stead, 2020). Flood engineering is essential to territorial planning (Picon, 2005), but the increasingly obvious instability of man-made systems, linked as much to the intrinsic dynamism and speed of the inherent transformation processes as to the unpredictability of climate change (Maleksaeidi et alii, 2016) has made it clear that certain planning and design models are not capable of dealing with current environmental challenges (Turkelboom et alii, 2021; Picon, 2005). In managing flood risk in river environments, the operational limits of traditional approaches based exclusively on the advance definition of a preferential state of stability and its constant maintenance by adopting rigid engineering solutions (Figg. 2, 3) that employ static, constricting infrastructures (Rossano, 2015; Nobert, Krieger and Pappenberger, 2015) are becoming increasingly evident.

Rather than freezing the territory and its natural ability to change, (Mathur and Da Cunha, 2014), we should rethink planning practices in a way that encourages, instead of inhibiting, the ability to develop that is intrinsic to river ecosystems (Da Cunha, 2018; Michener and Haeuber, 1998). In order to transform a state of fragility into an opportunity (Grêt-Regamey et alii, 2015; Rossano, 2015), we have to reflect on the definition of the concept of risk, both in conceptual and regulatory terms. It is widely acknowledged that risk is the product of both a hazard and its consequences (Kron, 2005): far from being a simple exercise of definitions, understanding the concept of risk is of fundamental importance to understanding where and to what extent we can take action to best direct planning and design practices for areas exposed to the risk of river flooding.

In the specific case of man-made systems located in high-risk river environments, since it is impossible to take action to lessen the intensity of a hazardous event (unless indirectly through reduction of the causes behind climate change) and it is extremely difficult (from practical, financial and even social standpoints) to relocate well-established settlement or production systems like urban areas or agricultural production areas, it would seem apparent that the main way to reduce risk would be to take action to reduce the vulnerability of the system itself (Sharma and Ravindranath, 2019).

More specifically, the scientific definition of that concept makes it clear that the idea of vulnerability is exclusively caused by internal factors (sensitivity and the ability to adapt; IPCC, 2014). This shows how it is possible, at least theoretically, to reduce the risk by acting directly on the system and improving its capacity to evolve each time in response to external events (Sharma and Ravindranath, 2019). That is why the

Fig. 1 | The Po di Volano river flows through the first suburbs of Ferrara (credit: the Authors, 2022).

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Fig. 2 | Constrictive system, rigid embankment of the Lana River, Tirana (credit: the Authors, 2021).

Fig. 3 | Lamination basins along the Parco del Delta del Po, Sacca degli Scardovari (credit: the Authors, 2021).

goal of this paper is to define potential areas of work for the design and planning practices in order to encourage, in systems exposed to flooding risks, flood management and protection actions that foster the transformational and evolutive tendencies of the landscape. The sections below set out successful examples of landscape designs and plans with effects on the reduction of risk, there is an assessment of regulatory assumptions that guide design practices linked to river systems in an Italian context, and finally, these issues are applied to a case study of the river Po in the Emilia-Romagna region, underlining how this could be a pilot project at European level both for its landscape-environmental importance and its economic and social role.

Strategic and planning approaches for developing landscapes | Starting from the acknowledgement of the undeniably artificial nature of all landscapes and ecosystems (Hobbs et alii, 2006; Emanueli and Lobosco, 2016) and far from making yet another rhetorical proposal of the natural element as a planning instrument (Morton, 2009; Pasini, 2020), the interpretation of ecological landscape design (Van Der Ryn and Cowan, 2007) through Nature-based Solutions – NbS (European Commission Directorate-General for Research and Innovation, 2015) turns out to be an essential strategic assumption to create resilient landscapes that are continuously developing, i.e. that can adapt to the most unexpected need to change as dictated by extreme climate events. Even though there is a vast array of types and ranges of applications of NbS (EEA, 2017), for this paper, we would like to point out the great success that these

types of solutions have had in the area of river area flood risk management through the restoration of areas that previously formed part of the river and are returning to their initial function (i.e. hosting changeable, dynamic habitats) by reconsidering them through design and planning practices of landscape architecture. In this context, NbS contain an incredible variety of approaches to dealing with risk (World Bank and World Resources Institute, 2018; Sudmeier-Rieux et alii, 2021), and as opposed to traditional, rigid engineering solutions, prove to be extremely versatile instruments that can adapt to the specific morphological and typological characteristics of the various territorial environments and respond to the ever different and unpredictable environmental challenges in a more relevant, focused fashion (Schindler et alii, 2014; Albert et alii, 2019, 2021). Examples of reduction of flood risks through NbS incorporate both prompt actions being taken at the design stage along with systematic interventions as part of programmes that operate at the territorial level.

An example of the first category is the ecological-environmental-landscape restoration of the Shuicheng river (China 2009-12) from a Turenscape project that proposed the renovation of 90 hectares of wetlands devastated by decades of uncontrolled industrialisation through projects aimed at slowing down the flow of rainwater, improving water quality, and restoring native habitats (Fig. 4). The new ecological infrastructure entails the entire drainage basin of the Shuicheng river (Fig. 5). The water courses, wetlands and floodplains were integrated into rainwater management and purification system through the creation of a series of stormwater management ponds and wetlands. This approach both reduces floods to a minimum and increases the base flow to support the flow rate of the river after the rainy season. The concrete embankment of the artificially channelled river built in the 1970s was also removed and replaced by a natural riverbank comprising a vegetation terrace system that can be flooded to regulate the flow of water and revitalise the riparian ecology. This action returned the river to a state that could accommodate its dynamism, accommodate possible spatial changes and give back a significant public space to the community.

With regard to the second category, we would like to mention the Dutch Programme Ruimte voor de Rivier (Room for the River), developed by the Dutch Directorate-General for Public Works and Water Management (Rijkswaterstaat) from 2006 to 2015, which aimed to reduce the risk of flooding in areas close to the main rivers (Meuse, Rhine, Waal and the Ijssel), following the 1986 Ooievaar Plan ideas to improve the spatial quality of river areas (Fig. 6). Even though the Plan recognised the importance of maintaining the dyke system on which the substantive survival of the entire area of Holland had been based for centuries, it decided it was necessary to restore, where possible, the natural dynamic river processes through relocation of the existing dykes further upriver, lowering the levels of current flood plains, creating more buffer zones and expanding the existing riverbeds. All the actions identified aim to increase the outflow and storage capacity of the rivers and, where possible, give more room to environmental dynamics and public recreational activities.

Some of the actions taken under the Plan include the highly interesting Nijmegen-Lent case (2012-16), where relocation of the dyke north of the river and the creation of a secondary waterway help the expansion of the river during flooding events or intense rainfall (Figg. 7, 8). There is a bottleneck in the Waal River at Nijmegen due to its specific geometry which often caused flooding in its historical centre. After the floods of 1993 and 1995 and in view of an increase in the risk of flooding due to climate change, the municipality decided to give more ‘room for the river’, while protecting the surrounding natural habitats and providing recreational spaces. The city, therefore, began to adapt the river and its banks, relocating the main dyke 350 m inwards and excavating a large river channel parallel to the original one. Upon completion in 2016, the project had managed to reduce the height of the river water by 35 cm. When the river is high, a third of the total quantity of water is diverted towards the new ancillary channel. The actions taken under the plan also created an island which is now used as an urban river park.

Another interesting project was the Lower Danube Green Corridor Plan (Fig. 9). In 2000, the governments of Bulgaria, Moldova, Romania and Ukraine, under the general supervision of the WWF, entered into the Lower Danube Green Corridor Agreement to establish a green corridor along the common banks of the Danube. This agreement, which has currently resulted in actual interventions on the final 1000 km of the river basin, aims to restore river plains which had been heavily compromised by intense reclamation in the second half of the twentieth century, and more specifically to re-

Fig. 4 | The new Shuicheng river terraces, Liupanshui Minghu Wetland Park, designed by Turenscape (credit: Turenscape, 2013).

Fig. 5 | Park design interventions, Liupanshui Minghu Wetland Park, designed by Turenscape (credit: Turenscape, 2013).

store 224,000 hectares of natural floodplain as an alternative to the traditional dyke systems Ebert, Hulea and Strobel, 2009; Mansourian et alii, 2019; Fig. 10). The agreement also aimed to reconnect the river to its natural flooding areas, reducing the risks of major flooding in areas with human settlements and offering benefits both for local economies (e.g., through fisheries and tourism) and for the environment. The outcomes from the project show that restoration projects have provided many benefits, including improved natural capacity to retain and release floodwaters, enhanced biodiversity and strengthened local economies through diversification of livelihoods based on natural resources. The implemented measures increase the resilience of the river system and local companies in managing current climate variability and the likely impacts of further climate change.

Regardless of the type of NbS used in the above-mentioned projects and plans, we

Fig. 6 | Ruimte voor de River territorial plan, Rijkswaterstaat 2006-2015 (credit: Mijs cartografie, 2014).

believe it is important to emphasise the ability of the NbS to generate further benefits besides solely reducing flooding risks, as much in the environmental area as in the economic social, urban and cultural areas (Schindler et alii, 2014; Raymond et alii, 2017; Seddon et alii, 2020). They provide an opportunity to both drastically reduce flooding-related risks and also to improve the hydro-morphological features of water courses, increase riparian biodiversity and restore damaged ecosystems. Further issues are those linked to raising awareness on issues like the management of water resources, the creation of new spaces for the community and retrieval of the history and identity of places by adopting design solutions that are inspired by traditional local landscapes. The examples given show how the adoption of an approach based on ecological landscape design criteria and their interpretation, in design terms, through the use of NbS, can make it possible to identify and exploit flooding risk as an opportunity to incorporate (or restore) environmental and spatial values within the scope of landscape projects (Raymond et alii, 2017; Seddon et alii, 2020), but, in order to make this possible, a basic requirement from the start would be the need to connect complementary issues such as reducing flood risks, restoring and boosting ecosystems and urban development into a single strategic planning system.

Correspondence between risk management, planning guidelines and design actions in the context of Italy | The relevance of the issue of hydrogeological[1] security in Italy has formed the basis for a broad range of policies over past decades incorporated into national and regional plans. We can take one of the most important rivers in Europe as a reference, the Po River (Fig. 11); the following documents were identified as examples to analyse the relationship between risk management and project works imposed by the planning practices: the Hydrogeological Structure Plan (PAI), the Po Hydrographic District Management Plan (PdGPO) and the Flood Risk Management Plan (PGRA). Due to the complexity and extent of these instruments, for the purpose of this paper, we decided to focus on the design goals and guidelines shown by each of them. This analysis aims to examine whether there is room to manoeuvre within the scope of the regulations to propose transformation strategies for the river environment aimed at improving it in terms of environmental resilience.

The PAI, established by Italian Law 183/89, is the cognitive, regulatory and technical-operational instrument through which: 1) it recognises hazardous factors that exist in the territory and the definition of boundaries of the affected areas; 2) the actions and

Fig. 7 | New cycle/pedestrian crossing and new wetland ecosystems on the sideof the I-Lent Riverpark Nijmegen, designed by Lodewijk van Nieuwenhuijze and H+N+S landscape architects (credit: COAC, 2016).

Fig. 8 | The new river channel of the I-Lent Riverpark Nijmegen, designed by Lodewijk van Nieuwenhuijze and H+N+S landscape architects (credit: COAC, 2016).

Fig. 9 | Lower Danube Green Corridor territorial plan (credit: WWF, 2010).

measures to safeguard those areas are planned; 3) the conditions of use of the land are defined by the characteristics of the hydrographic systems and aimed at maintaining an adequate level of safety. Despite the stress put on the indispensable nature of maintaining and strengthening the engineering works currently in place to protect the territory, we should note how the Plan recognises, among its main objectives, the importance of restoring the function of the natural systems (including through reduction of the artificiality resulting from the defence works), the restoration, redevelopment and protection of the territorial environmental features, restoration of the river areas for recreational use, hypothesising strategic guidelines for interventions aimed at safeguarding and, where possible, expanding the natural flooding areas of the water courses, and in general, reducing manmade interference with the developing dynamics of the riverbeds and river systems.

The Management Plan for the hydrographic district of the river Po (Autorità di Bacino Distrettuale del Fiume Po, 2021a), drawn up by Directive 2000/60/EC (European Parliament and Council of the European Union, 2000) and transposed into Italian law through Italian Legislative Decree 152/06 (Repubblica Italiana, 2006), defines technical and operating instruments to optimise the use of water resources and achieve a good hydromorphological state of the rivers for both controlling potential impacts on human health and to guarantee the maintenance of biodiversity. More specifically, the Plan reiterated the need to encourage coordinated actions that aim to both protect and improve the state of aquatic ecosystems, terrestrial ecosystems and wetlands, while also helping to reduce the effects of flooding and drought.

Finally, in compliance with European Directive 2007/60/EC (European Parliament and Council of the European Union, 2007), and through Italian Legislative Decree 49/2010

(Repubblica Italiana, 2010), the Flood Risk Management Plan was prepared (Autorità di Bacino Distrettuale del Fiume Po, 2021b), an operating instrument conceived to identify and plan the actions needed to reduce the negative consequences of floods for human health, the territory, assets, the environment, the cultural heritage and economic and social activities. The five main goals identified by the Plan, which became strategies at the district level following the 2021 update, emphasise the wish to ensure more space for rivers. The lack of effectiveness (and non-sustainability) of the traditional technical-water approaches to ensure infallible and non-discriminatory protection against flooding is recognised in clear, unequivocal terms.

On the other hand, it reiterates the potential of solutions like revitalisation of the geomorphological and ecological functions of river systems, and the fact that implementation of green infrastructures mean both protection against flooding and the encouragement of informed, sustainable use of the land, the improvement of environmental conditions, the generation of habitat and landscape diversity, the storage and improvement of basic ecosystem services and the promotion of territorial development and resilient urban planning. It is also considered vital to operate in the entire catchment area upstream of metropolitan areas to ensure sustainable practices in land use which can help reduce flooding peaks, improve the retention and drainage capacity of the water in urban areas and provide for controlled flooding of designated areas in the case of serious flooding.

The guidelines set out in the above-mentioned Plans combine contemporary design practices and water management where rivers are recognised as dynamic systems to support even before than considering them as unpredictable systems to protect ourselves from. Even though they take different approaches, the documents analysed underline the need for coordinated intervention in the areas exposed to the river flooding risk, paying the necessary attention to plans related to the ecosystems and the transformational and adaptive ability that characterise them (Grêt-Regamey et alii, 2016). To that end, there has to be agreement on the strategic approaches to take[2] and planned actions and multi-disciplinary projects have to be defined since they have to be ap-

Fig. 10 | Topographical work in the Danube floodplain at Mahmudia, Romania (credit: Cristian Mititelu WWF Romania, 2010).

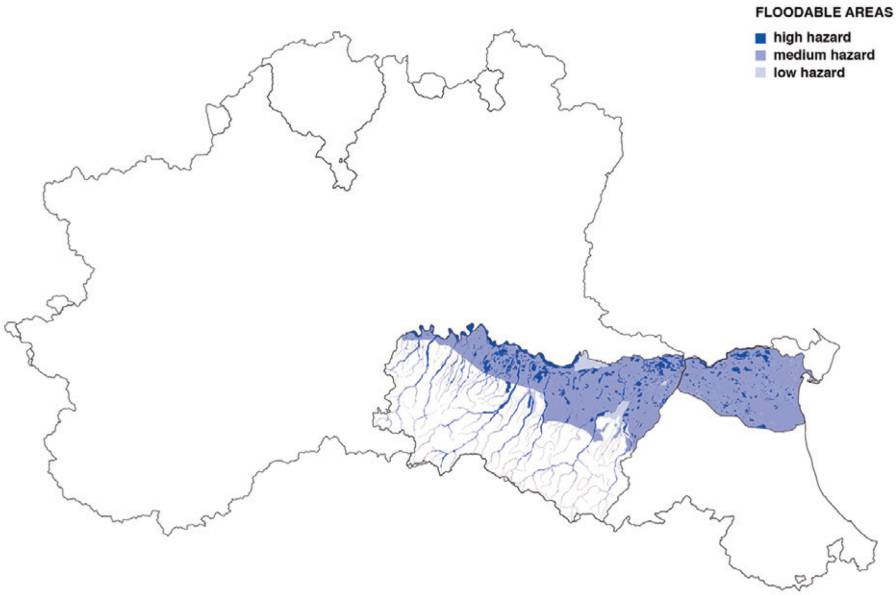

Fig. 11 | The Po River from above, note the complexity of the landscape traversed between urban, productive and agricultural systems (credit: apple maps, 2022).

Fig. 12 | Map of floodable areas within the management unit ITN008-Po in the Emilia-Romagna region (credit: G. Sartin, C. Mariani and Y. Nouira, reprocessed from National Geoportal and ABDPO data, 2022).

plied to transform the regulatory guidelines into reality, taking the positive aspects introduced and putting any operational or conceptual limits up for discussion.

Prospects for the Po River in the Emilia Romagna area | The vast size and environmental complexity of the hydrographic basin of the river Po exposes it to a diverse range of extraordinary flooding events (Domeneghetti et alii, 2015). Of these, those mapped between 2011 and 2020 in the entire management unit ITN008 – Po[3], 5 out of 8 are in the Emilia-Romagna territory. The exposure to risk in the area analysed, concerning the data set out above, is significant (Fig. 12). Most of the actions taken, that could be likened to the transformation of the landscape to reduce hydrogeological risk (embankments, water layouts, expansion banks), are purely of an engineering nature with no thought put towards issues of fundamental importance for river environments such as biodiversity. As shown by the examples analysed in the paragraphs above, some exceptions are distinguished by the greater care put into the design and references to broad-ranging strategies that include bigger areas of territory.

Starting from those assumptions and the input dictated by law, it would be possible to take action in a coordinated, widespread manner along the entire length of the river Po by reconsidering the typical aspects of the surrounding territory, i.e., its agricultural nature. Agricultural areas, which represent 46.6% of the entire regional territory in Emilia Romagna (Istituto Nazionale di Statistica, 2020), are sensitive areas for the management of water and flooding risk since there is a close connection with the territorial water system managed by the reclamation consortia. It should be possible to create a widespread system by selecting the agricultural areas that adjoin the irrigation infrastructure or the course of the river and subsequently transform them into wetlands for application of the NbS to create a more varied rural landscape that is environmentally richer. Acting as an ecological corridor as opposed to the current uniform countryside traversed by the Po River, the new wetlands would act as a quantitative and qualitative control instrument of the surface waters, ensuring adequate space for water storage where natural cycles of constructed wetlands could be created (Kadlec et alii, 2000).

Like surface water, similar issues arise with regard to aquifers, and underground water deposits that can help manage water and consequently reduce risk. The development of MAR systems – Managed Aquifer Recharge (Dillon et alii, 2019) to transform fields that consume water into accumulation and percolation recharge systems would allow for the creation of a series of water-connected systems that could manage rainwater in a constant, widespread and integrated way. A key role in this process could be carried out by the Forested Infiltration Areas (AFI – Aree di Infiltrazione Forestale; Fig. 13), i.e., woods with deep-rooted trees established for production purposes to enable water to permeate more quickly into the ground, preventing evapotranspiration (Mezzalira, Niceforo and Gusmaroli, 2014). According to the proposed template, instead of the current uniform scenario, the future agrarian countryside could evolve into a more varied system where the strictly productive agricultural areas could be interspersed with new wet ecosystems to reduce the risk of flooding and improve water management (Fig. 14). Even though theoretically, this should not be difficult, the strategic and planned position linked to the transformation of agricultural areas would incorporate complex issues such as the political and strategic interaction with specialist associations, the definition of criteria that could help select and transform the areas, a strategy for financially compensating the land owners (Felloni, Magagnoli and Tinti, 2019).

In accordance with Regional Law no. 24 of 2017 and through the Urban and Ecological-Environmental Quality Strategy which underlines how 'the new types and requirements thereby become those of resilience, i.e., the ability to adapt' (Regione Emilia Romagna, 2017), new integration possibilities have been introduced for territorial planning and landscape transformation actions. This opportunity will have to be grasped to renew planning and design methods to apply to contexts of high hydrogeological risk. Using a multi-disciplinary approach, preliminary processes could be initiated to improve the space and the environment, in addition to integrated risk management. The new financial assets allocated at European Union and national level are going in that direction: the Po River may obtain an overall allocation of about €360 million as part of the National Recovery and Resilience Plan commitments (Italian Government, 2021). The Italian Minister for Ecological Transition (MiTE) has agreed to a project to revitalise the Po area where wide-ranging action has to be taken for environmental and ecological restoration.

The project provides for improved management of hydrogeological risk with revitalisation action to be taken along the entire course of the river to reactivate the natural processes and encourage restoration through reforestation, the control of native plant species and the reduction of riverbed artificiality. If added to large-scale territorial plans, these strategic-design guidelines would allow for a reduction in hydrogeologi-

Fig. 13 | Bosco Limite, forest infiltration area in Carmignano di Brenta, Padua (credit: Bosco Limite, 2019).

Fig. 14 | Landscape transformation's scenario in the Po river area situated in the Province of Ferrara (source: Felloni, Magagnoli and Tinti, 2019).

cal risk, and more especially for the regeneration of a very widespread environmental network in the territory with positive, immediate impacts on the ecosystems involved (Keesstra et alii, 2018; Jakubínský et alii, 2021). The NbS-based adaptation and resilience approaches provide flexible, cost-effective alternatives that can be broadly applied to pre-empt climate change while simultaneously overcoming the many disadvantages of rigid infrastructures (Jones, Hole and Zavaleta, 2012) which now characterise the entire course of the Po River.

There is a widespread desire (or actually necessity) to establish a new reading of waterways that reinterprets the traditional static model of channelised rivers (Hartmann, Slavíková and McCarthy, 2009; Bengtsson et alii, 2003; Christensen, 1997). By overcoming this concept, we move closer towards the idea of systems in dynamic equilibrium, whose mobility and adaptability are factors that reduce water hazards, enrich habitats and enhance the value of the countryside. To that end, the agreed attempt to take a broader view to promote the restoration and revitalisation of river ecosystems through the definition of actions that deal with the issue of water management becomes clear (Werritty, 2006; Wesselink et alii, 2015).

Conclusions | The necessary awareness to deal with climate challenges must rapidly develop into integrated planning and design practices to complement the urbanisation processes and territorial transformation through a merger of theoretical and practical ideas. Converting the possible risk factors from potentially hazardous elements into design assumptions, going beyond the traditional segmentation typical of current rigid management models, and integrating approaches like the ecosystem-based approach and instruments such as nature-based solutions will enable a reduction in the territory's vulnerability to extreme water events.

As emerged from an analysis of the above-mentioned planning instruments, Italian planning already seems to incorporate the rudiments of the assumptions needed to implement the NbS on a territorial scale. Therefore, the challenge is to develop an approach that can keep design actions and territorial planning together in a single, consistent system through the definition of strategies that are both capable of avoiding or reducing the effects of a potential hazardous event and that can also promote the informed use of the areas impacted by the intervention. Therefore, the task of urban and territorial planning is to define the consistent use of space over the medium-long term (Ahern, 1999) which can help the development over time of the NbS and related benefits so that they do not become a further barrier – albeit green – to use of the space, but a reason to enhance the value of the river environment and its ecological-environmental components (Farina and Belgrano, 2004).

Two fundamental issues, summarised below, emerged when attempting to define the theoretical assumptions needed to draw up a large-scale strategy, where the use of the above-mentioned instruments will have to both respond to current needs for climate adaptation and risk reduction, and also allow enhancing the value and regenerating the environment, economy and culture of the territory and the countryside:

1) a reconceptualisation and reconsideration of the river environments as hybrid infrastructures; the river must be regarded as a highly dynamic environmental system, continuously developing, a landscape in transition that must be capable of being expressed in its coherent artificiality, also by better water management; leaving aside nostalgic and environmental trends, but respecting an environmental system for what it is or what it should be, we would like to confirm that the transformation (consistent and specific) of river environments and surrounding areas in accordance with Eda and NbS criteria is a priority to reduce the risk of flooding of river bodies;

2) the proposal of procedural and operating models that tend towards interdisciplinary planning processes based on mediation – rather than the abuse of power – between the individual interests and the needs in play right from the start and for the study of the project; to ensure the proper balance between water safety goals and landscape and environmental goals, control and coordination booths will have to be created, i.e. multidisciplinary commissions comprising town planners, ecologists, engineers and geographers, specifically aimed at monitoring the development of each plan and design from the formulation stage up to its completion, and ensuring that each action taken both reaches the necessary safety standards, and also generates spatial quality and promotes the cultural value of the countryside (Klijn et alii, 2013; Sijmons et alii, 2017).

In conclusion, we confirm that the Italian framework is a fertile one, both in terms of spatial preparation (its lack of uniformity makes it an open-air laboratory for design and planning issues) and in terms of regulatory conditions that seem to chart the right path to take in terms of operation. However, we need to experiment with these guidelines at a practical level, since we will only be able to validate the results or make critical corrections of the operational-methodological premises by directly applying them.

Notes

1) In Italy, 5.4% of the national territory is subject to a high probability of flooding, with 16,223.9 km^2 and 2,431,847 inhabitants involved; for more details, please see the ‘Rapporto sulle Condizioni

di Pericolosità da Alluvione in Italia e Indicatori di Rischio Associati' (lit. Report on the Conditions of Hazard from Flooding in Italy and Associated Risk Indicators; ISPRA, 2021).

2) For the projects to work on an extensive territorial scale, all the parties involved will have to be willing to cooperate (territorial and local public entities, private entities, the civil protection authorities, management consortia and trade associations).

3) For the purposes of the Flooding Directive requirements 2007/60/EC, the hydrographic district of the Po River is divided into 5 management units; the biggest is the ITN008 – Po, with a territorial extension of 70,311 km^2.

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NATURE-BASED SOLUTIONS AND BIOPHILIC DESIGN
Eco-systemic approaches to regeneration

Lidia Errante

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ABSTRACT
From the perspective of ecological transition, environmental design has assumed a central role in political strategies and design thinking on urban regeneration and energy and technological upgrading. The improvement of the environmental performance of cities and buildings tends toward two major results: higher quality of life and places according to socio-economic and aesthetic-cultural criteria; a balanced relationship between the built environment and the natural environment, with the related energy and ecosystem benefits. The contribution reflects the trans-scalar character of environmental regeneration and redevelopment processes in the broad spectrum of solutions suggested by the biophilic approach. Nature-based solutions are discussed as a means to pursue the improvement of the physical, social and environmental quality of the urban and built environment.

KEYWORDS
nature-based solutions, biophilic design, eco-system services, urban and technological regeneration, quality of life

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The worsening environmental and climate crises have radically changed attitudes on the sustainable regeneration of cities, oriented towards a trans-scalar, holistic and metabolic approach to redefining the balance between the natural and anthropic spheres. The widespread concept of 'urban landscape' denotes the need to identify the ecosystem of elements (artificial and natural) that populate it, and the dynamics of co-existence, production and transformation. Humankind and their environment are experiencing the point of greatest tension due to the intensive exploitation of the planet's resources and the need to adapt to increasingly adverse conditions. Cities represent the outcome, synthesising contradictions at all scales: local and global, physical and social, anthropic and natural, and becoming the terrain of complex challenges, well portrayed by the Sustainable Development Goals and strategies for ecological transition (UN, 2015; European Commission, 2019, 2020) of which the health, energy and geopolitical crisis have accelerated the pace.

These dramatic circumstances have rekindled the theme of economic, social and environmental well-being by associating it with two existential paradigms often left out of the narrative: the quality of public space, both urban and residential, and the relationship with nature. From a post-pandemic perspective – as well as in that of the 2030 Agenda (UN, 2015) – it will be crucial to make cities and human settlements more inclusive and sustainable, including in terms of social and climate justice, by reducing emissions, increasing the absorption capacity of pollutants in the urban environment and supporting ecosystem services through the introduction of Nature-based Solutions – NbS (Cataldi et alii, 2010).

The energy crisis has increased the race to improve the energy efficiency of buildings, which had already begun in recent years in Italy as well, thanks to the introduction of tax incentives known as Bonus and Super Bonus. These measures, adopted mainly on the building envelope and air conditioning systems, reduce dependence on gas consumption and non-renewable sources for heating and cooling buildings through better thermal insulation. This can be achieved through a holistic approach using biophilic design and NbS. The ongoing ecological transition process involves a broad spectrum of sustainable, political, social and design behaviours, which brings out an ecosystem perspective on air quality, and climate change mitigation, in which health and urban ecology are closely connected. These concerns, in line with the most recent urban sustainability strategies and practices – from the 2030 Agenda (UN, 2015) to the New European Green Deal for 2050 (European Commission, 2019) – are reflected in actions and design approaches aimed at improving the well-being and quality of life of communities also through nature-based solutions and technologies.

Goals and methodology | The contribution is part of a broader post-doctoral research project on Sustainable Building financed by the Region of Calabria (FESR FSE Funds 2014-2020) for the development of an innovative and sustainable system aimed at assessing the environmental quality and containment of energy consumption in residential buildings. The methodological premise is to identify interpretative models, regeneration strategies and sustainable recovery technologies for trans-scalar interventions in residential neighbourhoods, through interventions in public space – including mobility – and buildings. The contribution discusses possible design approaches and technological solutions capable of supporting local environmental and cultural ecosystem services and the environmental quality of cities in general. The first part will discuss the new design needs that emerged in the current socio-economic and cultural conditions. The second part will examine design approaches to ecosystem regeneration according to NbS, their typologies and applications for improving urban and territorial resilience (Mussinelli et alii, 2018). The third part investigates the technological applications of such solutions – green technologies and biophilic approach – in urban regeneration and building rehabilitation. The interventions are classified according to a taxonomy constructed from the action generated – addition, subtraction, replacement, thickening, integration – and the possible applications (Fig. 1).

A taxonomic matrix (Fig. 2) is built according to references and case studies to understand the design expressions given by the combination of technological choices and performance requirements on an aesthetic and formal level. Reference is made to Sergio Los's (2013) reflection on the 'epistemological turn' of sustainable architecture and the 'implications of sustainable design in architectural theory'. An attempt is therefore made to select cases in which 'instrumental acting' and 'communicative acting' of the project activities in synergy accompany the cultural evolution of man in the conscious process of transformation and adaptation of the environment through technology. In the current era, which Los would have described as an inter-somatic, ante litteram vision of the Anthropocene, the environment has been overwhelmed by the transformations of man and technology. On the contrary, we are witnessing a renewed awareness, both social and design-oriented, oriented towards the naturalisation of the existing through hybrid, heterogeneous, fluid city forms, mixed and multi-programmatic, multi-dimensional, multi-functional urban landscapes (Gausa, 2022).

The contribution discusses some of the possible strategies of urban regeneration and sustainable recovery, practices and solutions, oriented to improve environmental comfort, and suggests energy alternatives and new symbolic and cultural relations (Los, 2013) through projects and meta-projects of a techno-performative nature (Gausa, 2022). The field of sustainable design considers the city as an urban ecosystem, characterised by infrastructures and high population density, and including green and blue environmental infrastructures of pristine nature – forests, oases and protected parks – and man-made nature – cultivated areas, parks, gardens, courtyards, green roofs, trees (FIU et alii, 2020). Hybrid forms are not excluded, where natural elements meet urban and peri-urban areas in wetlands, rivers, canals, streams, lakes, ponds, and urban forests. In this sense, the contribution reflects the project's ability to support Ecosystem Services in terms of climate and atmospheric regulation, resource regulation and supply, biodiversity, and recreational services aimed at the leisure and aes-

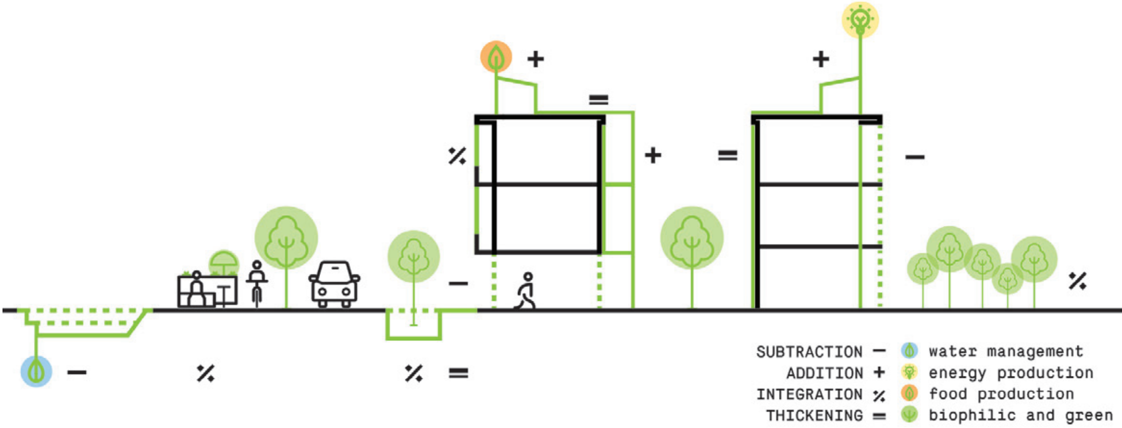


Fig. 1 | Diagram of design actions (credit: L. Errante, 2022).

Fig. 2 | Taxonomic matrix of reference case studies (credit: L. Errante, 2022).

thetic value of places (MEA, 2005). Regulatory Services and Cultural Ecosystem Services represent the most important categories for the sustainability of an urban ecosystem in terms of environmental and social quality (FIU et alii, 2020).

With this in mind, the contribution discusses approaches to urban regeneration and rehabilitation of the existing that can support and enhance the benefits provided by ES in terms of sustainability, healthiness and liveability of the urban and built environment.

Biophilic design and nature-based solutions | The issue of environmental quality and sustainable transformation in contemporary cities defines the project – urban, architectural, technological – in terms of complexity, transversality, adaptability, multiscalarity, multi-functionality, and hybridisation. Some authors suggest an image of an open, flexible, alternative urban environment, capable of adapting to its inhabitants (Sennet and Sendra, 2022) and to the natural ecosystem in which it is into, recognising the degree of disorder and unpredictability of the transformative processes that characterise both society and the urban landscape. The sustainable project is based on the relationship between the natural, urban and built spheres, and it is interesting to observe the renewed centrality of the envelope, the surface, the cover layer, the land use, and the skin as an interface between the natural and the artificial, with an estimable value from an ecological and economic point of view (Cataldi et alii, 2010).

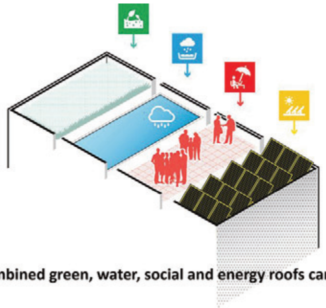
Sustainable design should participate in urban naturalising but it is also important to manage the skills and the knowledge required for green design, to design cross-cutting and complex solutions at the appropriate scale (Kabisch et alii, 2016). Reflecting on sustainable urban regeneration and building redevelopment processes, the contribution focuses on viable solutions to the design of public space and the building envelope, examining approaches that respond to different socio-cultural and technical-performance requirements.

The evolution of the know-how on environmental design, bioclimatic and regionalist architecture (Los, 2013) shifts from the house-local climate paradigm to the built-natural environment paradigm, with similar assumptions. The key element is the rationalisation and maximisation of resources to mediate between the performance requirements that guarantee comfort and wellbeing for individuals and the conditions posed by the context, both from a climatic and morphological point of view, formulating appropriate design solutions and technical-constructive expedients. Today, due to the worsening climatic emergency, these technological solutions related to the natural elements are not just appropriate, but complementary and compatible, through positive and functional use of natural resources for a better environmental performance of the built environment and rebalancing the relationship between city, society and nature.

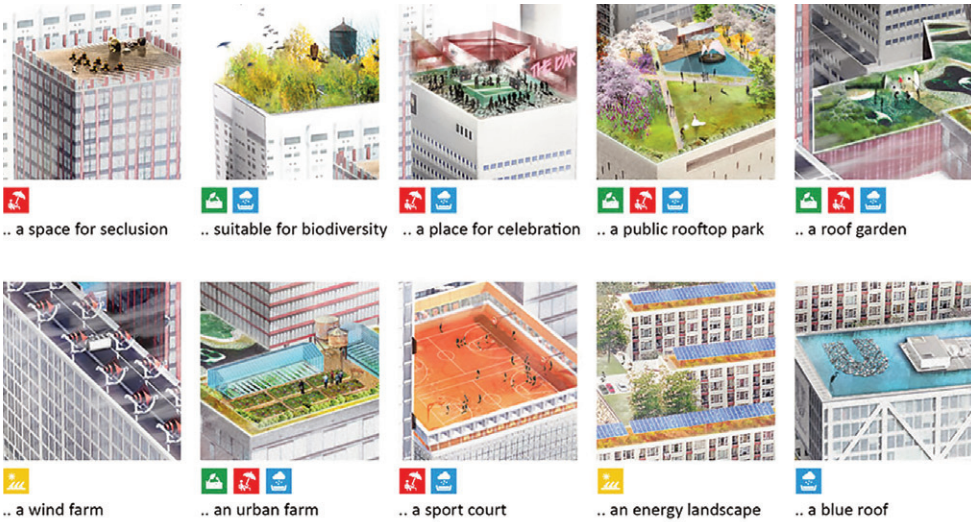
The integration of Nature-based Solutions (NbS) into technology and process choices is pursued with these assumptions oriented towards trans-scalarity, adaptability and biophilic design. The aim is to reintroduce nature into human experience, through aesthetic, material and graphic (Figg. 3-5), organic or artificial characteristics, recognising its benefits also in terms of the physical and mental health of individuals



Figg. 3-5 | Passeig de Sant Joan, project by Lola Domenech (credits: A. Goula, 2012).



Figg. 6, 7 | Rotterdam Rooftop Strategy (credits: De Urbanisten.nl, 2021).



(McDonald and Beatly, 2021). According to the European Commission (2021), NbS embody a socio-ecological innovation, already foreshadowed by Horizon 2020, considered effective in terms of economy, resilience and biodiversity through systemic, locally adapted and resource-efficient interventions and ecosystem services.

Eggermont et alii (2015) propose three types of NbS, differentiated by level of intervention. The first, is oriented to Nature Climate Solutions and includes the protection and conservation of endangered ecosystems to preserve biodiversity. The second involves the definition of functional management models aimed at the agricultural landscape. The third, more intrusive, implies new artificial ecosystems using green technologies at the urban scale. This classification defines the aim of the contribution to discuss the limitations associated with climate warming mitigation strategies in the urban and built environment through the use of NbS. For the naturalisation of the urban and built environment, reference is made to transformation actions of the public space and the building envelope that are useful to favour evapotranspiration, shading, reduction of the heat island effect and urban flooding. Technological solutions acting through addition, subtraction, integration and thickening of horizontal and vertical surfaces are analysed.

Design and technological opportunities | NbS provide a concrete response aimed at increasing the resilience of the built environment by supporting urban and cultural ecosystem services (Morabito, 2021), an opportunity for technological advancement and social innovation oriented towards the achievement of transversal and multi-scalar solutions (European Commission, 2021). The debate on the deployment of NbS focuses on their actual technological maturity and integration with traditional technologies, as opposed to their total replacement (Osaka, Bellamy and Castree, 2021). Research has examined NbS as suited for the built environment (Fig. 2) and its greater ecological convenience for the regeneration of existing neighbourhoods and buildings instead of the new construction of 'green cities' (Scalisi and Ness, 2022).

The green roof is among the best known NbS, capable of performing multiple actions for the building and its occupants, including thermal insulation and potentially increasing biodiversity and food self-production, with benefits in terms of energy savings, improved microclimate and reduced heat island effect. At the core of the Rotter-

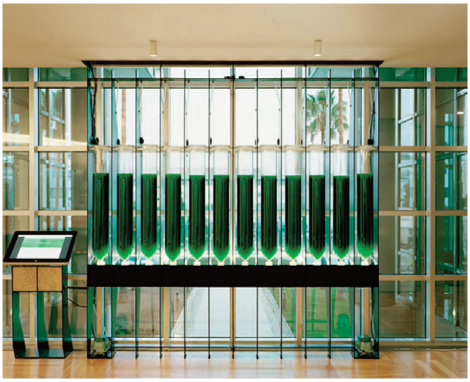


Fig. 8 | Bio Intelligent Quotient (BIQ) House, Hamburg, opened in April 2013 (credit: Colt International, Arup Deutschland, SSC GmbH).

Fig. 9 | Application of PhotoSynthetica technology, developed by ecoLogicStudio for air filtration through the use of spirulina algae on the facade of the Nestle factory in Lisbon (credit: ecoLogicStudio).

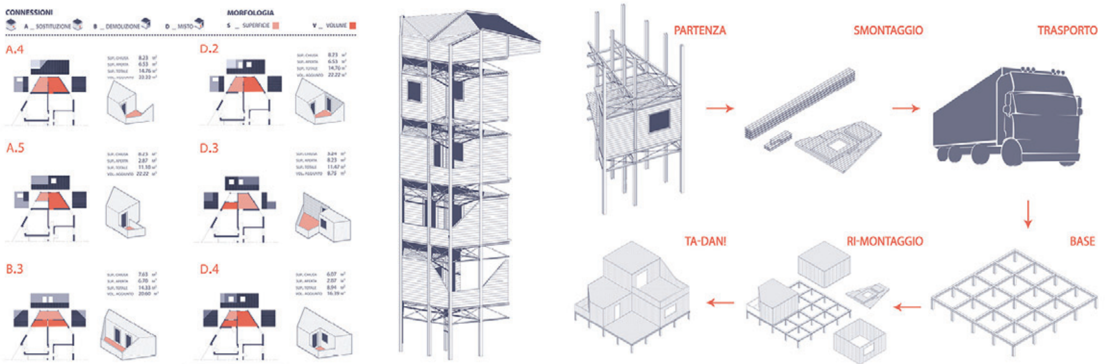


Fig. 10 | Functional additions in bio X-Lam on the façade of an existing residential building (credit: A. Quattrone, 2020).

Fig. 11 | Thailand, Thammasat University Rice Terrace Rooftop (credit: Citypopup.net, Landprocess).

dam Roofscape – Programme for Multifunctional Roofs strategy is the encouragement of various sustainable rooftop functions (Figg. 6, 7): green areas, water drainage and energy production systems, social and mobility, new housing and building management facilities. The integrated approach involves the combination of several functions placed according to the needs of the area and a monitoring programme of the intervention in terms of adaptation and mitigation (Gemeente Rotterdam, 2019). The programme is an emblematic case of the political ability to converge climate, social and design objectives through the collaboration between public authorities, in this case, the Munici-

Fig. 12 | Watersquare in Rotterdam by De Urbanisten (credit: De Urbanisten).

Fig. 13 | Watersquare in Rotterdam by De Urbanisten (credit: L. Errante, 2018).

pality of Rotterdam, and architectural signatures such as MVRDV and De Urbanisten, in charge of the design of access and plan of the Roof Landscape, respectively.

The green roof is a widely assimilated NbS from a technological and conceptual point of view and, for this reason, is also more easily implemented in terms of cost-benefit. Even with similar performance and micro-climate requirements, a study by the Politecnico di Milano reveals a substantial difference in construction and maintenance costs, which is higher for the installation of green walls (Morello, Mahmoud and Colaninno, 2020). On the other hand, there are numerous green roof alternatives for the direct and indirect thickening of the vertical surface of buildings, using light containment structures or cladding elements that provide for the housing of soil for

Figg. 14, 15 | Watersquare in Rotterdam by De Urbanisten (credits: L. Errante, 2018).

cultivation. The NEST (Natural Eco-System Tiles) system, one of the winners of the New European Bauhaus Prize 2021, is a technological solution aimed at improving the building's environmental conditions and thermal and acoustic insulation performance through an element made of local clay and designed for vegetation and nesting (Scalisi and Ness, 2022). The application of NbS to the building envelope is not limited to the vertical forestation paradigm, although it does support urban biodiversity. Innovation in this regard is the use of algae for CO_2 absorption (Scalisi and Ness, 2022) and the production of biofuel and organic fertiliser. This assumption supports the ecoLogicStudio's design research, experimentation, and realisation of the bioreacting façade, a shading system with algae in saline suspension that absorbs CO_2 and produces biogas with an annual increase of 4,500 kWh per year added to the 32MW of solar thermal energy available for the building (Fig. 8). Similarly, the design of a greenhouse as an air treatment systems with appropriate plant species or algae, to ensure the thermoregulation and filtration of air. This nature-based technology is scalable from the building to the environmental unit (Fig. 9). These NbS, integrated into buffer zones between the building and the environment, maximise its environmental and thermal insulation performance, collaborating in the eco-compatibility of building technology choices. Experimentation in this sense has been conducted for the design of functional additions through dry-built structures in bio X-Lam, according to the circular principles of design for disassembly, as part of the meta-design research for the sustainable recovery of the 'INA CASA Sbarre Inferiori' district in Reggio Calabria (Errante and De Capua, 2021; Fig. 10).

Alongside punctual solutions, urban NbS at the scale of public space is equally capable of enhancing ecosystem services and urban green infrastructure, with benefits on a social and recreational level, as well as climatic and environmental. From boulevards to the banks of watercourses running through the urban fabric, green and blue corridors can be imagined that can dispose of and slow urban flooding and, through vegetation and organic material, filter pollutants in water and air (Morello, Mahmoud and Colaninno, 2020). Can be noted that there is a benefit in shading, reducing the heat island effect and capturing particulate matter at the deposition level for the use of urban forestation, including linear trees, or permeable and semi-permeable pavements with plant inserts, which do not necessarily have a positive impact on ecosystem services.

This is due to two critical issues. On the one hand, the interaction between the planted species and the infrastructures below the road level is an obstacle that can be overcome through technological green and driveway solutions or with the aid of more complex solutions, in terms of functional stratification, such as the Cupolex Radici system. On the other hand, the selection of plant species must be oriented to guarantee both respect and an increase in biodiversity, as well as possible inconveniences for the health of individuals such as allergies and respiratory disorders. Another aspect that is not secondary is related to the shading projected by tree foliage onto buildings. For example, it will be appropriate to plant deciduous trees to the south, so that the sun's rays permeate during the winter and screen them in the summer months.

Such considerations can guide the correct design of parks and gardens to produce benefits at different scales, from the city to the indoors, also favouring activities of self-production and self-sufficiency in energy and food (Fig. 11), cohesion, a sense of belonging and regeneration of social commons. Examples include productive gardens planted with fruit trees or 'bee gardens' with flower varieties that promote pollination as a fundamental ecosystem services. Within the public space, street furniture can also be conceived, designed and selected as NbS. Shade zones, pergolas and green roofs, urban seating providing housing for vegetation, and the provision of cool urban oases with controlled ventilation and temperature.

An interesting configuration of public space is the water square, a water square built at lower heights than the street, generally accessible by stairs and steps, capable of containing large volumes of rainwater and regulating its runoff in a controlled manner. The case of Bonthemplein in Rotterdam (Figg. 12-15) is an international reference in this sense, with impacts on the environmental quality of urban space and liveability. The urban resilience strategy is enriched in formal and aesthetic values by treating surfaces and articulating diversified spaces for sports and recreational activities. The system of squares, arranged to respond to the principle of communicating vessels, is also the result of a participatory process mediated by the designers themselves (Errante, 2020).

Conclusions, limits and future developments | Today, the ecosystem approach to urban regeneration and building rehabilitation appears fundamental to providing alternative, credible and sustainable responses to energy efficiency, health and safety in the built environment. The NbS presented here does not represent an exhaustive picture of the panorama of environmental design, but the efforts made by policy, design and technology toward the integration of nature as a building material, mitigation and production tool and biochemical processes capable of constituting energy alternatives. The evolution of technology also accompanies designì towards a progressive but partial mixing of languages and communication codes related to sustainable architecture. Green technologies, the expression of performance and functional requirements are now understood, promoted and defended by politics and society.

In the face of numerous design and technological opportunities capable of rethinking the transformation of the urban and built environment as and through NbS, several authors (Scalisi and Ness, 2022; Osaka, Bellamy and Castree, 2021) still highlight some criticalities, especially in terms of process rather than design. On the one hand, the difficulty of modifying the erosive dynamics of urban expansion, which NbS alone cannot be able to compensate for. On the other hand, NbS may be economically costly compared to other technological solutions considered more 'mature', less unpredictable and more easily monitored in the short and long term. In the absence of proper cost-benefit assessments or quantifiable data, the adoption of NbS could potentially prove detrimental to the ecosystem balance and the health of individuals. In this sense, in addition to academic research efforts to formulate possible indicators of the effectiveness of NbS in combating climate change (Kabisch et alii, 2016; Sowińska-Świerkosz and García, 2021), the European Commission (2021) provides practical and theoretical support and evaluation tools for different dimensions of intervention (strategic, spatial planning, soft engineering, technological performance).

These efforts, supporting the formulation of nature-based policies, plans and projects, do not overcome the skills gap found on the theoretical and practical level, which slows down the concrete implementation of NbS and the related socio-economic and technical-performance impact study in the long run (European Commission, 2021). The dissemination of models for assessing and monitoring the impact of projects adopting NbS may also highlight the benefits of hybrid, natural and man-made, digital and cyber solutions with high environmental performance, with particular reference to clean and accessible energy production technologies. The sustainable exploitation of natural resources provided by the context through biophilic design and the use of NbS contribute to an ideal of a green, clean, healthy, productive, self-sufficient and resilient city, an ambitious goal that moves in the increasingly dramatic perspective of combating the environmental crisis and promoting climate justice.

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PATIENT-CENTRED AND TECHNOLOGICAL-CENTRED APPROACHES
Patient room adaptability solutions

Cristiana Cellucci

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Abstract
Starting from the study of the spatial/technological organization models of the hospital room (Intensive Care Patient Room, Acuity Adaptable Rooms, Universal Bed Care Delivery) and the main trends regarding the modernization of the architectures of the Italian National Health Service, increasingly attentive to the human dimension and the digital/technological dimension, the paper aims to define design alternatives for the hospital room, trying to combine spatial/technological flexibility with organizational flexibility to optimize workflow in care processes and the appropriateness of spaces to the psycho-physical-social well-being of all the users involved.

Keywords
patient-centred vision, bio-technology-centred vision, intensive care patient room, acuity adaptable rooms, universal bed care delivery

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The current setup of Italian PNRR[1] (National Recovery and Resilience Plan) identifies a series of reforms and investments that will have to lead our National Health Service (NHS) towards a change, starting from the criticalities that emerged during the Covid-19 pandemic. If on the one hand the emergency situation following it confirmed the quality of our NHS hospitals, on the other hand it highlighted the fragility and weaknesses of a rigid system from a spatial, functional, technological and organizational point of view, though it was able to cope with the emergency by resorting to extraordinary initiatives (closure of departments, home treatment through Usca, allocation of Covid patients to homes for the elderly or temporary structures in buffer zones).

However, the attempt to counter the pandemic phenomenon led to awareness of the potential that certain innovations can have in terms of resilience of hospital structures, such as: 1) user-centred solutions for flexibility of environments through the adaptability of some departments to accommodate Covid patients through temporary solutions (separation/division of patients/spaces), showing the potential that a flexible design attentive to the relationships/integrations between spaces-equipment-systems and dividing elements can have in terms of optimizing activities, improving productivity, 'centrality of the patient' (user-centred approach) and in terms of response to a condition of uncertainty/emergency; 2) technology-centred solutions – such as e-health, telemedicine, imaging, digitalization of functions, robotic systems of service/assistance to personnel – showing the potential that the new technological frontiers can have both in terms of organizational complexity (miniaturized intra-body technologies, interventional robotics, Interactive Systems, sensors and monitoring actuators) and management (Big Data, AI, digitalization), in the dense network of relationships between spaces, equipment and users (Figg. 1, 2).

The same PNRR, on the one hand, underlines the need for a holistic vision of health as psycho-physical and social well-being by expanding it – in the concept of One Health[2] – to the interconnections between health, environmental and climatic fields and in the even more up-to-date approach of Planetary Health, to well-being and social equity throughout the world, through balanced governance of the political, economic and social systems that are decisive for the future of humanity and the natural systems of the Earth (Whitmee et alii, 2015). On the other hand (in component 2 of Mission 6 of the PNRR, 2021) it highlights the urgency of digital modernization of the hospital technology park, focusing precisely on the organization of healthcare on 'technology-centred' solutions with implications/changes in terms of both organizational and managerial complexity.

It emerges that the main challenge that all of us – technicians, health professionals and scholars – are called on to face is to overcome or rather combine the dualism of Technical Progress and Humanization. Dualism is increasingly characterised by the conflict between the hyper-accelerated dynamics of health technological innovations – whose positive effects on health must not be forsaken – and progressive awareness on the part of every citizen of their dignity, their rights and their conscious and uncon-

Keywords search string	acute care, intensive care, acuity adaptable rooms, universal bed care delivery model, health and environment, hospital design, healthcare facility design, hospital planning, hospital management, ward design, isolation and infection control, fall incidence and prevention, patient occupancy rates, patient transfer, design and well-being, patient-centred care, cooperative care, patient room, private rooms, single occupancy rooms, semi-private rooms, multiple occupancy rooms, patient rooms, double occupancy rooms, social interaction, privacy, nursing efficiency in hospitals
Eligibility criteria	**Architecture and Design** Healthcare Design, Hospital Design, Healthcare Interior Design
Nature of the topic	**Hospital and healthcare** Health Facilities Management, Infection Control, Hospital Infection, Critical Care Nursing, Services Management
	Social, Psychological and Behavioural Environmental Psychology, Environment and Behaviour, Behaviour, Health Psychology, Social Psychology

Tab. 1 | Keyword identification and eligibility criteria used (credit: C. Cellucci, 2022).

scious willingness to participate in the healing process on which architecture in its component of an emotional, perceptive and sensorial nature can play an important role (Del Nord, 2006; de la Fuente-Martos et alii, 2018).

The prospect of convergence between the two approaches, within hospitals, can be expressed in the hospital room, which represents the place the patient interacts with most and the one in which activities related to personal and private life are conducted; at the same time it constitutes the space in which patients are given treatment and their state of health is monitored. The design approach may be oriented towards providing spaces with standards and technological equipment that can be implemented at a later time, to be conceived as 'software' that is updated with a level of flexibility not linked to the contingent moment but projected into the future. In particular, the field of biomedical technologies allows us to configure the Patient Room as a real Bedside Point of Care, that is a care model that reduces the patient's movements so as to reach interventional and imaging technologies, making each room the hospital's spatial and clinical 'centre of gravity'.

Through an analysis of the recent scientific literature, the objective of the paper is to identify the main trends in the design of the functional area of the hospital. Several strategies were used to identify potential studies/articles. Firstly, a keyword search was conducted in relevant databases, such as ABI/Inform, EBSCO Host, EMBASE, JSTOR, Medline, Pubmed, Science Direct, World Cat, and further information was gathered from secondary sources such as research centre archives (Health and Care Infrastructure Research and Innovation Center, International Academy for Design &

Health, Center of Health Design). Secondly, the 'potential studies' were compared in relation to the eligibility criteria referring to three macro-areas – Architecture and design, Hospital and healthcare, Social, Psychological and Behavioural – in order to separate the results included in the sphere of application from those outside this sphere and avoid distortions generated by selection through keywords (Tab.1).

Bibliographic research (120 selected papers) has shown that patient room models that adapt to the complexity level of the disease – known as Intensive Care Patient Rooms, Acuity Adaptable Rooms, and Universal Bed Care Delivery Models – are the main trends in patient room design and involve considerations on the layout of the entire functional area of the hospital. Starting from an analysis of the main critical issues concerning the traditional spatial/organizational solutions of hospitalization from which the first reflections on people-centred models (patient-centred, family-centred, medical-staff-centred) have been derived, the paper identifies three main thematic axes with respect to which different organizational/spatial/technological solutions are analysed to optimize the 'flexible room' model: 1) adapting the hospital room to the level of complexity of the pathology; 2) balancing the technological complexity with the human dimension; 3) improving the organization of staff work through decentralized nursing stations.

For each strategic axis, case studies have been identified, representative of the design trends, analysed in their criticalities and peculiarities with respect to the possible users (patient, visitors and medical/assistance staff), summarized in a matrix that illustrates and relates spatial/technological flexibility to organizational flexibility in order to optimize the 'workflow' in care processes and the appropriateness of spaces to the psycho-physical-social well-being of all the users involved (Fig. 3). Evaluation/verification of the solutions of the three thematic axes with respect to the points of view of the different users constitutes the element of originality of the contribution, which does not aim to define the characteristics of an absolute spatial/organizational model but, through the definition of a complex framework research not yet consolidated, to provide a framework of design alternatives that can be selected based on the priorities and specificities of the hospital's economic, social and environmental contexts.

Problematic environment: Intra-Hospital Transport | A recent survey by the Ministry of Health of the health facilities present on the national territory and their technological apparatus highlighted a widespread structural, spatial and technological obsolescence[3] and the consequent need to activate a process of modernization of the NHS – as demonstrated by the substantial investments in healthcare construction allocated by the PNRR (1,450,000,000) – in terms of effectiveness of interventions (from the urban scale, to the building, the hospital room) in production of health.

On the scale of the hospitalization room, various studies (Ferenc, 2014; Murphy, 2020; Sunder et alii, 2021; Eilers et alii, 2021) have shown that the hospital of the future will be designed with single rooms designed to accommodate various care and

Figg. 1, 2 | Pierangeli Nursing Home, Pescara, Italy (credits: S. Camplone, 2019).

health activities in which not only infection control but a more efficient care service will be better guaranteed. These are solutions related to Acuity-Adaptable care/Universal care models, already tested in some hospitals (e.g. in some hospitals in America such as Cathedral Hill Hospital, MultiCare Good Samaritan e il Memorial Sloan-Kettering Center), which go beyond the traditional approach to assistance in which patients are transferred (intra-hospital transport, IHT) from one unit to another in search of the correct level of care, towards a 'patient-centred' model of hospital rooms adaptable to the level of complexity of the pathology (low/medium intensity), eliminating patient transfers from ordinary to sub-intensive and intensive settings. The evidence shows that transporting patients has repercussions on managerial and clinical assistance aspects (Prandini and Zettele, 2013).

Several studies show significant correlations between transport and 1) increase in infection rates Eveillar et alii (2001); 2) increased medication errors, e.g. complications during transport related to airway equipment, infusion and drug equipment, monitoring equipment, etc. (Hendrich, Fay and Sorrells, 2004); 3) medical or clinical alterations, e.g. respiratory, cardiovascular, neurological, stress and anxiety problems for the patient (Zhang et alii, 2022); 4) risk of back injury or more generally of musculoskeletal disorders for staff due to manual handling of patients, considering that the average age of the typical nurse has increased to 47 years (Brown, 2007); 5) higher service costs and lower productivity (Hendrich and Lee, 2005). The vast majority of the time spent on intra-hospital transport is wasted on delays caused by communication problems, and delays in recording transfers or managing information about the availability of beds, equipment or staff (Ulrich and Zhu, 2007).

Intra-hospital transport of patients, therefore, represents an area of fundamental importance in quantifying the quality and efficiency of the care process, if we consider that transfers from one room to another – due to the need for additional technologies (imaging, surgery, other diagnostic or therapeutic purposes), the need for more qualified personnel (ICUs, are the most common origin of IHT) – are quantified in a measure of 2/3 times for short-term stays (Hendrich and Lee, 2005). Although some research argues that risk can be reduced with increased monitoring and support (Murata et alii, 2021), strong evidence indicates that in-hospital transport triggers complications and suggests the need to rethink the organizational model and architectural environment to minimize transfers through organizational solutions and spatial/technological models that adapt the staff and spatial/technological models to the level of intensity of care (Garg and Dewan, 2022).

Flexibility of the hospital room: literature review | The Acuity-Adaptable and Universal Room models, which have been experimented with in the United States since the 1970s, and became highly popular in the late 1990s, especially in highly complex specialist hospitals, have provided valuable lessons in long-term flexibility in spatial organization, technology of hospitalization rooms and organization of assistance centred precisely on the patient and the area he or she stays in. As these models have matured, their application and purpose have evolved and, in some cases, have become interconnected (Brown, 2007; Ferenc, 2014; Sunder et alii, 2021).

The patient's room adaptable to the acuity of the pathology is based on the single hospital room model in which the patient is treated/assisted during the entire hospitalization period and at any level of acuity of the pathology. The inpatient room model called Universal Care Room (UCR) is organized around the possibility of providing various technological plant and electro-medical equipment such as to be able to accommodate and manage any type of patient, regardless of the level of clinical complexity (e.g. intensive, med/surg). In most cases, the room set up for universal assistance is a hybrid of different types of rooms with the facilities provided for an intensive care room. Both models share the goal of flexibility to adapt space/technologies/personnel to the level of intensity of care but differ in purpose. In the Acuity-Adaptable model, the focus is on eliminating patient transfers by providing complete care directly at the patient's bed. By contrast, the goal of the Universal Room model is to provide a room with an adaptable design that can meet the changing needs of clinical acuity, without specifically altering the current care practice and patient transfer (Gallant and Lanning, 2001).

Although innovative, both solutions have the weakness of associating the flexibility of the room with an organizational model that is often difficult to implement, as certain services (cardiovascular surgery, neurology and trauma management) require different nursing skills and therefore a different staff based on the level of care (basic or acute nursing care), leading to staff organization problems (Ulrich and Zhu, 2007). As a result of these problems, a third model of care has emerged that divides Intensive Care Units (ICUs) from acute care rooms. It is a room model with beds adaptable to the required intensity of care and intended for patients who need intermediate care and possibly intensive care.

Adaptability of the space/equipment/technological system to the intensity of care | Adaptability of the hospital room to emergency conditions, through the analysed models, in order to manage the patient at the different levels of intensity of care directly from the bed, involves the integration of technological, electro-medical and functional equipment with respect to the different levels of care, within interstitial spaces present in attics, equipped floors or technical nuclei between the rooms (Brown, 2007; Ferenc, 2014).

Hamilton and Ulrich (2014) have identified three possible solutions for the integration of technological devices in the patient room, tested in different hospitals: 1) the 'headwall' configuration, in which the monitors and equipment sockets are positioned on the wall behind the head of the patient's bed, designed to be a flexible/customizable system to adapt to staff preferences; 2) configuration of the 'power column', in which the system of sockets/equipment is contained in a vertical device (from floor to ceiling) and generally placed sideways to the head of the bed, a solution that eliminates the need to move the bed but can cause interference with the flows/movements of staff during procedures or emergencies; 3) the configuration of 'suspension' systems, in which the life support components are suspended from the ceiling or the wall with the possibility of rotation of the system and adaptation to different bed positions (Pati, 2008). Although the latter is the most flexible and does not generate interference between electrical connections and movements of nurses/patients (reducing the potential risk of falling), the 'headwall' configuration is the most common choice among life support systems (Needham et alii, 2005). A concrete and innovative example is the headwall of the Jacobs Medical Center in San Diego in which electrical devices, oxygen and other medical gases are contained in a compact system that transforms a medical device into an architectural element (Fig. 4).

A potential criticality in the implementation of this model concerns the obsolescence of the technological apparatus for treatment and monitoring of patients, which involves the adoption of plant integration solutions that meet the requirements of disassembly, reversibility and implementability (Thiadens et alii, 2009). Specifically, the future challenges in integrating medical equipment into the patient's room will concern the following: 1) designing furnishings conceived not as aseptic objects intended

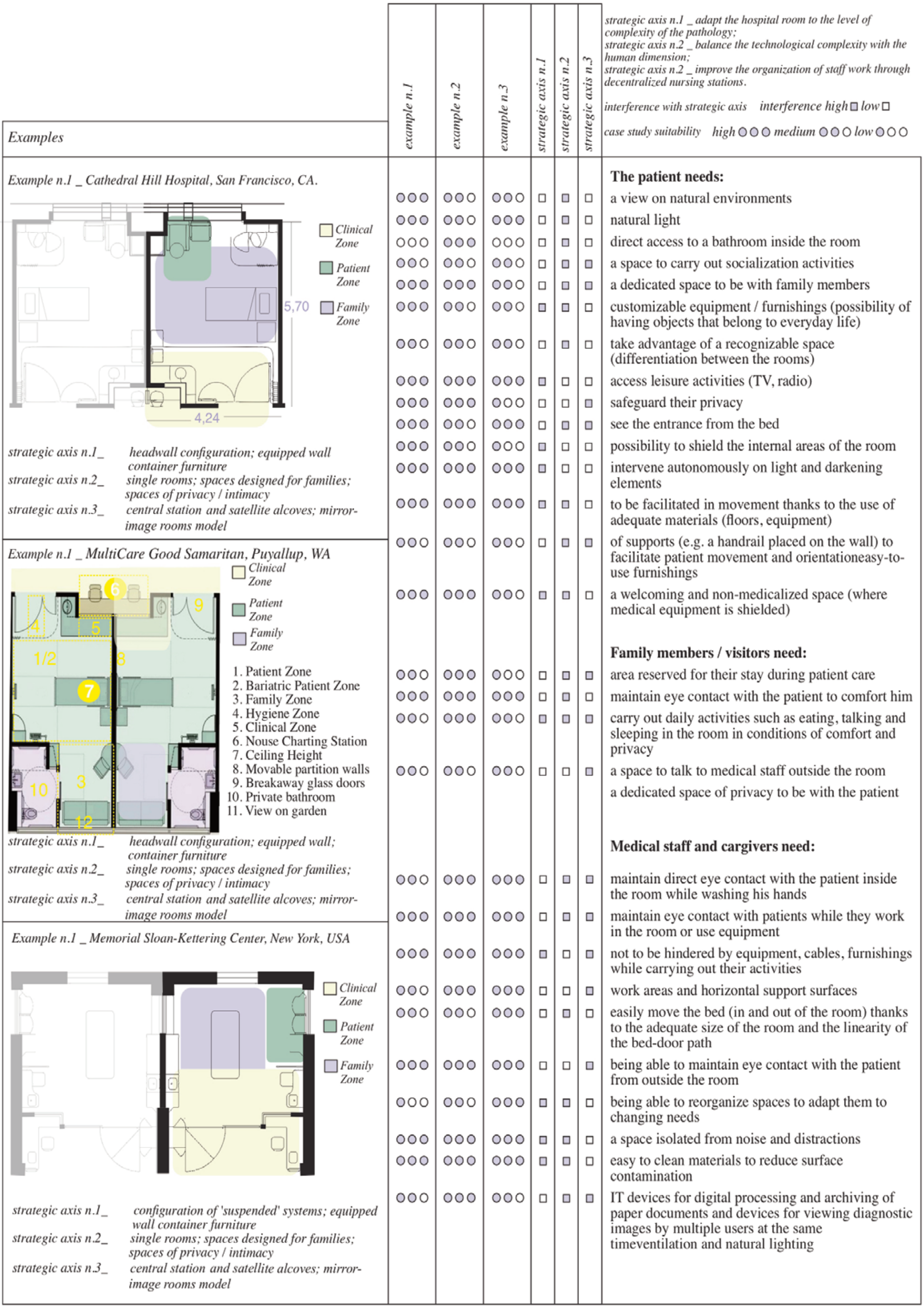

Fig. 3 | Evaluation matrix with respect to the needs of different users (credit: C. Cellucci).

to house medical equipment but therapeutic and wellness tools, integrated with new AI and robotic systems, capable of managing patients' medical information, monitoring vital parameters, distributing drugs or collecting samples, integrated with services capable of making sense of the time spent for treatment (internet, radio, television for personal use); 2) the use of technical interstitial spaces such as equipped floors and floors or technical nuclei between hospital rooms that can be expanded and integrated over time as the conditions of use change with respect to the individual conditions of the patient (intensity of care), which allow correct positioning and integration of sensors aimed at monitoring vital conditions. These interstitial spaces could be functional for the passage of the wiring for air, oxygen, and nitrogen at the service of the various bed stations with which they interface, as well as containing sensors (inserted in walls and floors) used to route trolleys, staff and patients along predetermined paths. All these devices can be hidden behind sliding panels with wooden or coloured finishes – to give the patient a positive perception – which can only be opened when using the equipment contained in them (Figg. 5, 6).

The adaptability of the hospital room to the evolution of technology must be supported by ergonomic considerations in the relationships between activities/spaces/equipment and users, which should ensure a 'wide fit' in the sizing of the room in order to provide for easy adaptability to different future organizational, spatial and technological conditions.

Balance between technological complexity and the human dimension | A common feature of the various adaptable room solutions is that of considering the methods, or 'how', through appropriate decision-making strategies, it is possible to create the environmental conditions to reduce the 'stress-inducing' factors and emphasize the 'stress-reducing' ones (Mokhtar, 2021). The approach to care through the patient-centred model has influenced not only the modalities of communicative exchange between patient

Fig. 4 | Jacobs Medical Center Headwall, San Diego (credit: shieldcasework).


Figg. 5, 6 | Walls equipped to accommodate the plant equipment of the Care Lab, by dmvA Architecten, Bruges (credits: B. Gosselin).

and medical staff but also the physical-functional (accessibility, distribution of spaces) and psycho-sensorial and perceptive characteristics of the care spaces, finding confirmation in Evidence-Based Design. Research experiences (Eilers et alii, 2021; Eijkelenboom and Bluyssen, 2022; Murphy, 2000) suggest considering the following strategies in hospital room design:

– Larger single rooms; rooms for single patients improve clinical outcomes by reducing the risk of infections, falls and stressful conditions, and at the same time ensure the possibility of configuring the room according to the need for positioning special equipment or wall space maneuvering for personnel to perform exceptional assistance activities (e.g. Loma Linda University Medical Center, California; Clarian Health System's Methodist Hospital, Ohio State University);

– Family-friendly spaces; the presence in the hospital room of a specific area intended to accommodate family members (including seating and services, and possibly beds) allows active involvement of family members in certain aspects of care as well as in psycho-physical support for the patient, with positive effects on clinical outcomes (decrease in hospitalization falls, reduction of nursing hours per patient) and on the increase in satisfaction with the hospital experience (e.g. Richard M. Ross Heart Hospital, Ohio; Clarian Health Methodist Hospital, Indiana);

– Spaces for privacy/intimacy; although the patient's room must respond to the needs of process efficiency and effectiveness of care, it cannot be neglected in a broader vision of health as psycho-physical well-being, with attention to characterization (for volumes, materials, colours) of spaces (New Children's Hospital in Finland, GAPS psychiatric hospital in Denmark) and personalization/appropriation of spaces for intimacy/privacy (the transformability of the wards in the Meyer Pediatric Hospital in Florence and the Agatharied in Germany); privacy must be particularly ensured during the later stages of hospitalization as patients typically only require intensive care ser-

vices for a limited period; this condition can be achieved through a spatial/functional organization of the room to avoid visibility of the privacy areas from the common areas or through movable partitions and glass doors that can be darkened;
– Healing gardens and positive distraction devices; the distributed presence of therapeutic gardens and healing gardens in which the internal-external correlation can be regulated by selective filters (light, air) according to the needs of users through the integration of automated systems (remote control of door, curtain and window opening, and lighting modulation), can affect the reduction of stress and improvement of clinical conditions by providing positive distractions for patients, families and staff. Other positive distractions often integrated into the room that can be adapted to the intensity of care are artworks, music and a family atmosphere (Isala Hospital in Zwolle, Holland, designed by Alberts and van Huut, 2013; Maggie's Cancer Center in Manchester, designed by Norman Foster, 2016; Figg. 7, 8).
– Environmentally responsible materials; another front is that of innovation in the field of building materials in which the frontiers of technological innovation focus on the possibility of having antibacterial and antiviral but also sustainable materials, free of toxic chemicals to improve internal air quality and reduce impacts on public health.

Decentralized nursing stations | Implementation of flexible solutions for adapting the patient's room to the levels of care also involves new solutions for the position of the nursing station. The traditional centralized nursing station – an operational model in which all the support spaces necessary for nurses to carry out their duties are located at one point in the physical hospital unit – is gradually being replaced by decentralized stations, in which nurses can directly see patient rooms so as to respond to problems more quickly. This solution makes it possible to reduce the time of assistance intervention (Pati, Harvey and Thurston, 2012), a greater interaction between medical staff and patient, better visibility of the patient and more time dedicated to his or her care (Hendrich, Fay and Sorrells, 2004). Many hospitals have experimented with the following nursing station solutions associated with Bedside Point of Care models:
– Nursing stations organised by clusters of hospital rooms; in this solution, the support spaces (which include spaces for documentation, drug storage, nursing supplies, equipment, etc.) necessary for nurses are distributed over several stations inside the physical hospital unit;
– Mini-stations between two rooms; in this solution, everything nurses need to perform their duties is provided immediately outside the patient room (or in the extreme case of decentralization within the patient room), Hendrich, Fay and Sorrells (2004) argue that after adopting this solution, Clarian Health System Methodist Hospital saw a decrease in the number of patient accidents by 75%;
– Hybrid service model; in this solution, decentralized service stations are combined with centralized service stations intended for meeting rooms for consultation between staff members; this model has been tested at the Banner Estrella Medical Center in

Figg. 7, 8 | Maggie's Cancer Center by Norman Foster, Manchester (credits: N. Young).

Arizona, with nursing alcoves outside each hospital room and a common workspace in each unit (with computer resources and small conference rooms), and is the best solution for designing nursing stations (Zborowsky et alii, 2010).

Other considerations to improve the nurses' workflow may concern:
– the orientation of the rooms according to the 'same-handed rooms models' (Parkland Hospital hospitalization room, Dallas, Texas) or 'mirror-image rooms' (Hallegiance Health solution); the former shares the wall that accommodates their headwalls, it is useful for positioning shafts/interstitial spaces functional to the headwall equipment; the latter places the headwall on the same side in all patient rooms, typically the left sidewall, which has been advanced as the optimum caregiver location; this solution encourages repetition and standardization that reduce the chance of errors and waste;
– the integration of ceiling-mounted patient lifts can be useful to reduce staff back injuries caused by lifting patients in and out of bed or a bathroom, staff sick time, and hospital costs (Fig. 9).

Conclusions | Although the concept of flexibility is very complex and includes a variety of characteristics such as versatility, redundancy, convertibility, transformability and scalability, the idea of designing a resilient structure capable of adapting to epidemiological, technological and social changes is always desirable, especially in light of the current Covid-19 pandemic. The solutions and alternatives analysed to improve the patient's room show that the physical environment can lead to positive results in terms of well-being (for users and operators); staff productivity (workflow); clinical safety (prevention of medical errors, incorrect application of therapy, contraction of nosocomial in-

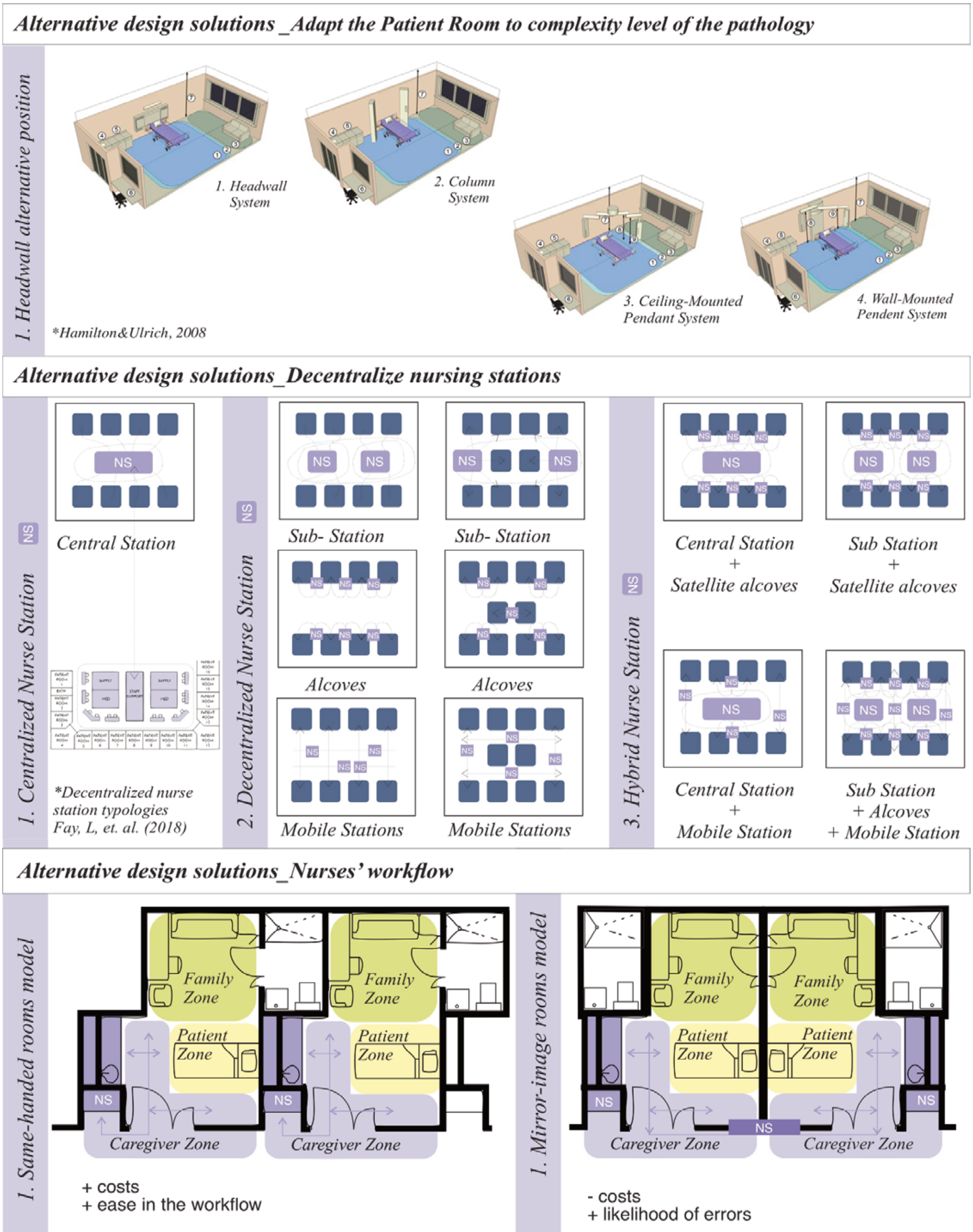

Fig. 9 | Alternative design strategies (credit: processed by C. Cellucci).

fection), psychological and physical safety, (prevention of medical errors, application of therapy, contraction of nosocomial infection and reduction of stress factors). However, the adaptability of the hospital room to meet these new needs clashes with the limits relating to the structural and typological constraints of existing hospitals, which constitute the main barrier to adaptation to new organizational/spatial models.

While for existing structures the transformations/adaptations should be appropriately evaluated from the point of view of feasibility according to the specific conditions of each structure in question, new hospitals constitute the main field of application of the solutions investigated. A further limitation derives from a rigid and cumbersome regulatory field of reference based on minimum structural, organizational and technological requirements (Presidential Decree 14/01/1997) which leave no room for creativity and design invention and would require alignment with international best practices (Health Building Notes; Healthcare Facilities Guidelines; etc.). There is also a problem of a psychological-behavioural nature due to the stressful conditions to which the medical-nursing staff will be subjected who find themselves working in new spatial models, with repercussions on tasks, duties, and workflows/habits. Precisely this complementarity between design actions aimed at guaranteeing the well-being of the users involved and organizational actions aimed at optimizing care suggest promising research spaces that can be investigated, further developed and possibly tested in real empirical contexts, through the involvement of figures belonging to different scientific disciplinary sectors in order to bridge the limits of a literature review conducted through databases (which may have led to exclusion of important contributions) and not on application cases.

However, the future research spaces in this field are ample, and the possible scenarios of use concern the development of tools for ‘verifying’ the adaptability of existing hospital structures; for ‘guidelines’, useful for public administrations in drafting innovative tenders for the construction of new hospitals; for ‘support’, for hospital strategic management and professionals to orientate actions towards new or existing structures, also through the use of simulation systems (Digital Twin) capable of verifying the possible transformation scenarios with the impacts on staff productivity, on the clinical safety/well-being of the patient and on accessibility to treatment.

Notes

1) The National Recovery and Resilience Plan is available on the web page: italiadomani.gov.it/it/home.html [Accessed 29 July 2022].

2) For more information see the web page: oneworldonehealth.wcs.org/About-Us/Mission/The-Manhattan-Principles.aspx [Accessed 29 July 2022].

3) Ricognizione del Ministero della Salute (2020), Rilevazione del fabbisogno di edilizia sanitaria, nota MdS prot. n. 17157 del 21/08/2020; Ricognizione del Ministero della Salute (2020), *Fabbisogno di informatizzazione*, nota MdS prot. n. 15809 del 31/07/2020.

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REMOVING AND STORING CARBON IN THE BUILT ENVIRONMENT
Green and grey solutions

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ABSTRACT
This paper investigates the potential of the combined use of ‘green’ and ‘grey’ solutions for removing and storing carbon in the interventions to regenerate the building stock, as relates to the goal, dictated by European policies, of halving carbon emissions by 2030 and achieving carbon neutrality by 2050. The issue is of great scientific importance in light of the European and national strategies and policies illustrated in the Next Generation UE Plan and the National Recovery and Resilience Plan (Piano Nazionale di Ripresa e Resilienza – PNRR). In particular, the paper illustrates the developments of research initiated by the Research Unit at ‘Sapienza’ University of Rome in the context of the PRIN (project of overriding national interest) ‘TECH START’ Research and of the ‘Climate-Pandemic-Proof Design’ Research, funded by ‘Sapienza’ University. This research was carried forward through the experimental application, in a public housing neighbourhood in Rome, of ‘green’ solutions (green infrastructures) and ‘grey’ solutions (CO_2 absorbing and low embodied carbon materials) working in synergy, systematically assessing their impact in terms of reducing climate-altering emissions from the current state.

KEYWORDS
carbon storage, carbon neutrality, carbon capture, embodied carbon, urban redevelopment

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Transforming and regenerating cities and urban areas into resilient, sustainable, and flexible organisms is a condition that can be put off no longer. The quality of living in urban spaces is of fundamental importance, and this includes adapting to and mitigating climate change, thereby contributing, with appropriate measures, to the decarbonization process (Tucci, 2018). The construction industry has a growing need for concrete strategies and actions to offset its emissions: reductions, removals, and/or offsets, to date yet to be systematically used in the built environment, are needed (Hirsch et alii, 2019; UNEP, 2020). This critical condition is the focus of this paper, which illustrates the developments of research carried out in the Rome-Sapienza operating unit of the PRIN (project of overriding national interest) Research titled 'TECH START – Key Enabling Technologies and Smart Environment in the Age of Green Economy – Convergent innovations in the Open Space/Building Systems for Climate Mitigation' (2019-2021) and the context of the Research, funded by 'Sapienza' University, titled 'Climate-Pandemic-Proof Design – Strategie, misure, sistemi tecnologici per la mitigazione climatica e la neutralità carbonica post-Covid' (2021)[1]. In particular, the paper analyzes the experimental application, in a public housing neighbourhood in Rome, of solutions capable of absorbing, removing, and storing carbon emissions from the atmosphere, belonging to two macro-concepts: 'green' and 'grey.' More generally, some of these solutions have already been in use, while others have the potential to be expanded, and others still appear only theoretical at present. The research proposes various solutions, estimating their performance impact on net carbon storage, and verifies their applicability and interaction while assessing their limits and opportunities.

Currently, the processes of capturing, transporting, and storing carbon are subject to continuous implementations to improve the process and contain costs, thus making them more efficient; these aspects are essential for extending these methodologies on a wide scale (Climeworks, 2020). As numerous studies have pointed out, the 'green' and 'grey' aspects are often treated separately, without grasping their interaction and with no unitary vision, while special problems are mostly discussed in greater depth (Kuittinen, 2021a, 2021b; Ariluomaa et alii, 2021; Amiri et alii, 2020). The results of these studies suggest that there is an underutilized potential for the systematic accumulation of atmospheric carbon in the built environment. The prospects, in particular as relates to storage, leave open problems that have yet to find adequate solutions as relates to sustainability, due to unacceptable areas of vulnerability.

The research assesses the tools and materials capable of absorbing and storing carbon from the atmosphere in urban and peri-urban environments, using 'green' and 'grey' procedures. The paper's originality lies in its combined use of 'green' and 'grey' solutions acting in synergy, to halve carbon emissions by 2030 and achieve carbon neutrality by 2050 (Calvo Buendia et alii, 2019). This arrangement aims at defining and cataloguing currently available solutions and strategies for reducing carbon emissions in urban districts, which are responsible for 36% of final energy consumption and 39% of total carbon dioxide emissions worldwide (IPCC, 2022).

Green infrastructure in the urban built space is intensifying as an affordable, long-term measure for mitigating the impacts of climate change, a measure that, thanks to its absorption capacity, contributes towards maintaining the water cycle in equilibrium and protecting the soil (IEA, 2022). Green infrastructure is an actual carbon sink and helps mitigate the greenhouse effect while containing the threats associated with the warming climate (Battisti and Santucci, 2020). The capacity to capture carbon is minimum in the leaves, larger in the branches and sprouts, and maximum in the trunk due to its diameter, and the soil; moreover, it varies depending on the plant species and other parameters that will be examined further on (Keenan and Williams, 2018).

In parallel, the research presented here takes account of another source of greenhouse emissions associated with buildings – a source that is less 'taken for granted': embodied carbon, which is to say the total of greenhouse gas emissions associated with construction, and particularly those derived from extracting, transporting, and manufacturing the materials (cradle-to-gate), which represent the main share of total carbon embodied in buildings. With the goal – crucial for decarbonization – of monitoring and mitigating this considerable share of emissions, which represent a total of 11% of global carbon emissions (Pomponi, De Wolf and Moncaster 2018; WGBC, 2019), the research identifies scenarios for intervention that use low embodied carbon materials, relying for example on wood or plant fibres for natural heat insulation, to exploit the carbon emissions stored in species suited to the production of these construction materials. In synergy with this approach, the paper considers experimentation activities based on the reuse and recycling of construction waste which prevent their elimination with the related economic and environmental costs, thereby incentivizing circularity and material resource efficiency and reducing embodied carbon through an improved process that includes design choices and assessments with a view to the life cycle, supported by LCA (Life Cycle Assessment).

Lastly, 'grey' solutions take into consideration the systematization of the technologies and processes available today for storing CO_2, for example, CCS (Carbon Capture and Storage), CCU (Carbon Capture and Utilization)m and DAC (Direct Air Capture), in addition to other experimental programmes (D'Olimpio, 2016; Global CCS Institute, 2021; Selosse and Ricci, 2017). As relates to these technologies, elements of use for their concrete integration with respect to natural solutions, and their potential applicability to the built setting are examined, through technologies and products that can be used safely and effectively today, so that they might contribute towards achieving the planned objectives.

Research methodology and operative phases | The paper relies on a review of the main methodologies currently present on the international landscape and capable of removing, absorbing, and reducing CO_2 emissions into the atmosphere, by assessing their aspects in terms of functionality, setting of use, production and cost/efficiency ratio, while carrying out interpolated comparisons among the various researched types.

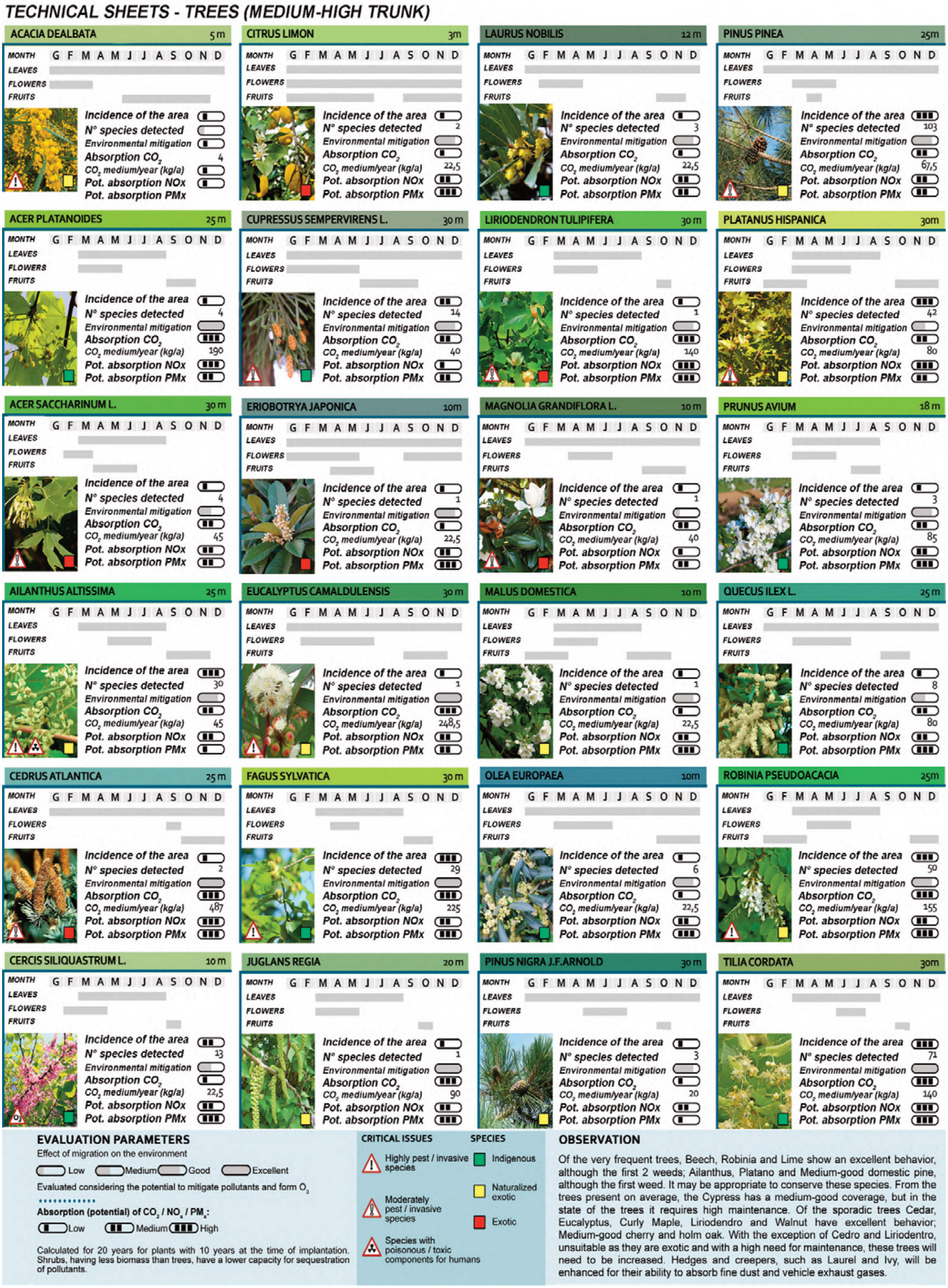


Fig. 1 | Data sheets of surveyed medium and tall tree species (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

The analysis process is developed in three phases. The first is reserved for quantifying CO_2 emissions for the investigation settings in accordance with the area's current state. The second analyses the advanced design options. The third takes stock of the examined issues.

The methodological approach applied for the ecosystemic assessment involves an analytic/evaluational examination, carried out also through an on-site survey and by systematizing the possible 'green' and 'grey' solutions, with the definition of two intervention scenarios. In this regard, important support was the tree census performed by the Municipality of Rome in June 2016 for each municipality, an implementation of the large tree survey that expresses a high value not only from the strictly botanical standpoint but in historical/cultural and scenic terms as well. This stock of knowledge, combined with direct surveys, provides a complete picture of the tree species that are present in the Mediterranean basin and have the highest carbon absorption capacity, thereby making the following possible:

– analysis of trees and species in accordance with specific parameters (autochthonous or naturalized, chorotype, biological form, use) with greater capacity for environmental mitigation to absorb and store CO_2 throughout the entire life cycle (Region of Tuscany, 2018);
– mapping of green surfaces;
– a survey of the vegetation that is present, with detailed quantification of the number of plants for each species;
– establishment of a database using the Office Excel Suite tool, aimed at systematically cataloguing each species while reporting the estimates referring to the plants' growth phases (during the first 5 years, the next 5 years, 20 years) and to the average overall value;
– preparation of a spreadsheet for the estimate relating to the vegetation's CO_2 absorption and storage in the current state;
– selection of the tree/shrub species endowed with the greatest capacity for CO_2 storage and removal of atmospheric pollutants derived from vehicular traffic, and fine dust (Fig. 1);
– preparation of the 'green infrastructure' project, with particular attention to autochthonous species, which guarantee a greater likelihood for success, and estimate of CO_2 absorbed and stored;
– verification of the ecosystemic benefits contributed by the proposed planning solution, considering the existing greenery and the new plants introduced, through comparison with the ex-ante status;
– rendering of the general situation of CO_2eq emissions derived from the energy system (heating, cooling, and lighting of the district) and the water, waste, and mobility system, to emphasize the role that vegetation and materials can play in the abatement of pollutants in the urban setting.

The adopted calculation method is founded upon assessment of the overall con-

Fig. 2 | Aerial photo of the San Basilio PdZ (credit: Cartoteca PDTA, ‘Sapienza’ Università di Roma).

Fig. 3 | Elevations of the buildings present in the San Basilio PdZ (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

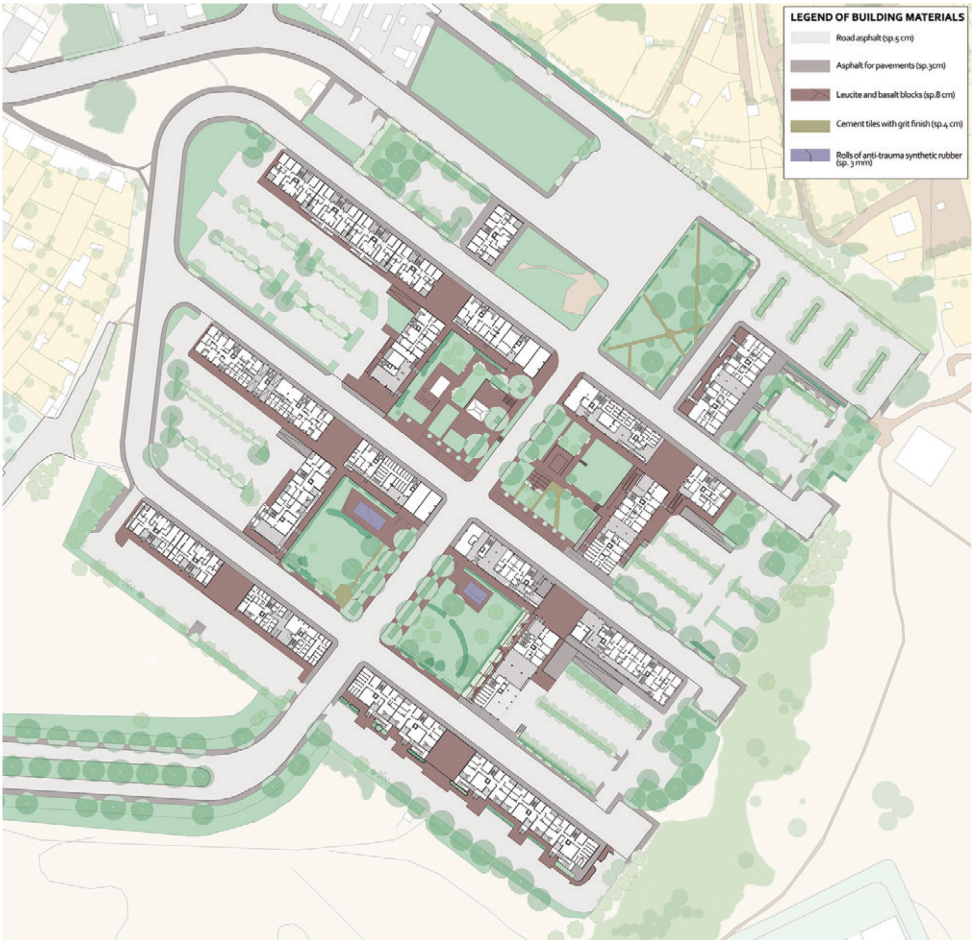


Fig. 4 | Census of building materials present in the current state (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

sumption in the study settings in terms of CO_2 and based on benchmarks, parametric data, and a modelling and simulation process with ENVI-met software, analysing the ante and post-operam situation. As relates to the 'grey' solutions, the phases of the methodology adopted in the project for the requalification of existing buildings and of their appurtenant external spaces are as follows: constructive analysis of the existing building for the purpose of characterizing it from the standpoint of performance, technology, and materials (a phase strictly correlated with the activities of evaluating energetic, thermal, and indoor living comfort performance); identification and quantification (in volume and weight) of the main materials present; estimate of the embodied carbon in the materials of the existing construction, based on the pertinent databases[2];

estimate (in volume and weight) of the materials removed from the building and of the corresponding embodied carbon; estimate of the requirement (volume) of materials for the intervention; identification of the materials recoverable in the intervention, including those that are the object of demolition; calculation of the shares (percentages in weight) of the materials that are recyclable/reusable on/off-site; selection of low-embodied-carbon materials and innovative materials with a capacity of storage or direct capture of carbon from the atmosphere; final accounting of the embodied carbon of the requalified buildings, with identification of the portions of emissions avoided through reuse in existing buildings, recycling of materials, adoption of materials with low embodied carbon or with CO_2 storage; calculation of the shares of emissions capturable over time thanks to the use of appropriate materials.

Lastly, the methodology calls for an overall accounting of the intervention scenario's emissions in comparison with the current state, in terms of CO_2 equivalent.

Experimentation on the case of the San Basilio zone plan in Rome | The experimentation involves analysis of the construction and scenic fabric of the zone plan of San Basilio located in district IV of the municipality of Rome (Fig. 2). Located by the city's ring road (GRA), the zone has an area equal to 136,991 sqm, within which are 2,500 public housing units equalling 12% of the total of those available in Rome. Seventy per cent of these units are managed by the local public housing agency (ATER – Azienda Territoriale per l'Edilizia Residenziale Pubblica) and 30% by the Municipality of Rome. The construction types that are present are characterized by terraced blocks of flats, with virtually uniform heights of a maximum of 7 storeys and conformation based mainly on 'closed-cell,' overlapping prefabricated elements, with slabs made with predalles defining the flats' internal partitioning (Fig. 3). Heat insulation is nearly non-existing, a situation aggravated by iron/aluminium single-pane windows and doors and plastic blinds that cause the dwellings to consume a great amount of energy for heating and cooling. The emissions amount to 3,606,178 $KgCO_2$eq/year, while the total embodied carbon of the main constituent materials equals 29,491,298 $KgCO_2$eq.

The district's open spaces, quantified as 86,603 sqm, are characterized by large, mostly degraded green areas (53.473 sqm) and by roads and resident parking. Bituminous asphalt was used for the roads and sidewalks, and blocks of leucite and basalt were used in the buildings' appurtenant areas and the district's four central courtyards, upgraded in 2008 with the introduction of play areas surfaced with anti-trauma pavement, small apparatus for resting, and a small snack bar kiosk. The pedestrian paths are in concrete tiles with grit finish (Fig. 4). The total embodied carbon equals 235,392,400.74 $KgCO_2$eq.

As for the greenery, the tree species that are present are mainly of exotic origin, with a strong prevalence of 'Ailanthus altissima', 'Cedrus atlantica', 'Robinia pseudoacacia', and 'Eucalyptus camaldulensis', often highly invasive with a medium-low quality of environmental mitigation and of the capture of pollutants (Fig. 5). The in-

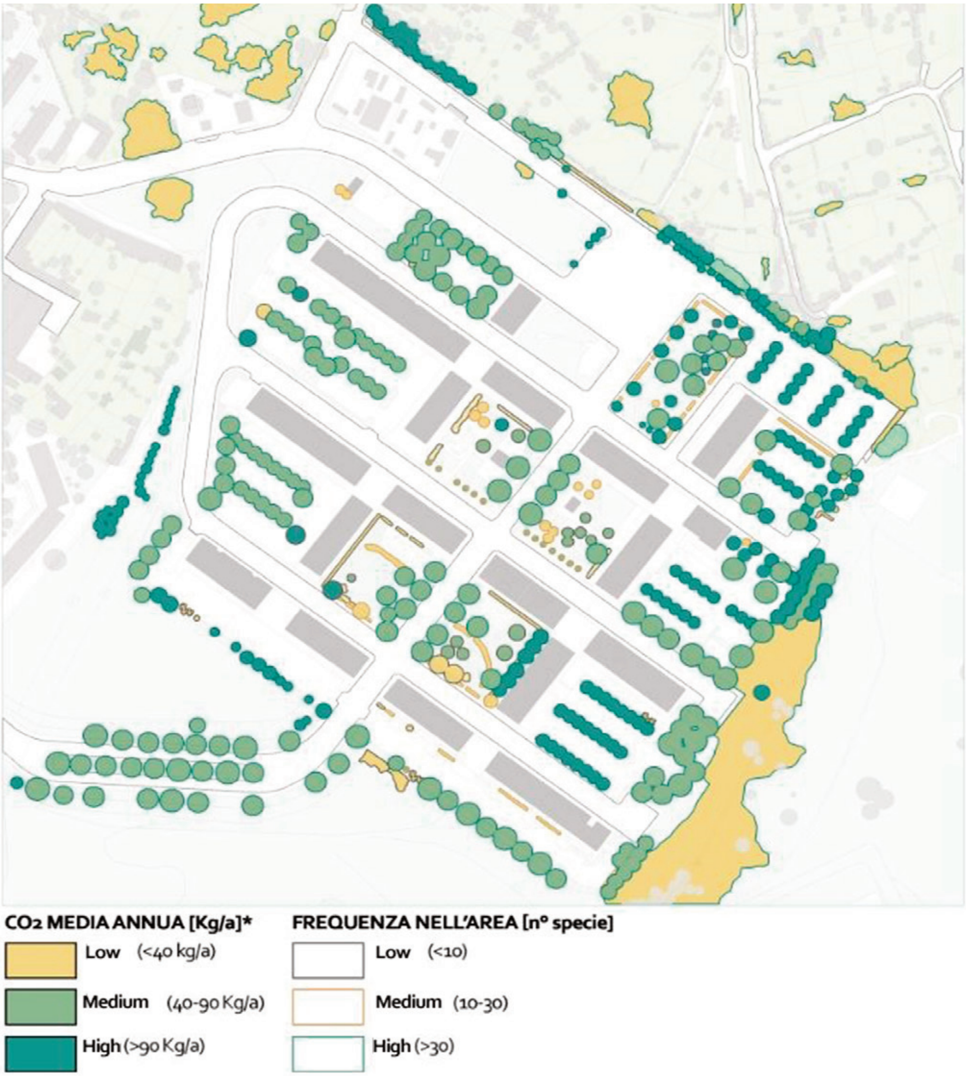


Fig. 5 | Overview of CO_2 by absorption capacity (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

spections that were performed identified 24 types of tree species for a total of 374 medium- and high-trunk trees, with a canopy cover equal to 30% of the open spaces. For each species, a technical data sheet was drawn up, reporting the parameters of environmental mitigation and of capacity for absorbing CO_2 from the atmosphere[3] (Fig. 6). The total absorption potential, including ground-level green spaces, is estimated as 360,577 $KgCO_2eq$/year.

'It is also observed that the neighbourhood lacks systems to manage, save, and

Fig. 6 | Overview of Native and Exotic Flora (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

reuse the water cycle, as well as systems to capture rainwater. In the current state, the energy needed for the water cycle produces emissions equalling 63,485 Kg-CO_2eq/year. The waste collection that is practised is door-to-door, with a separation percentage not exceeding 50%, in keeping with the average for municipal territory, and generates emissions equal to 3,880,351 KgCO_2eq/year. The neighbourhood is poorly served by public transportation (ATAC) lines – daytime, weekdays, and holidays. However, within a 2 km radius is the Rebibbia B-line metro station, and the sta-

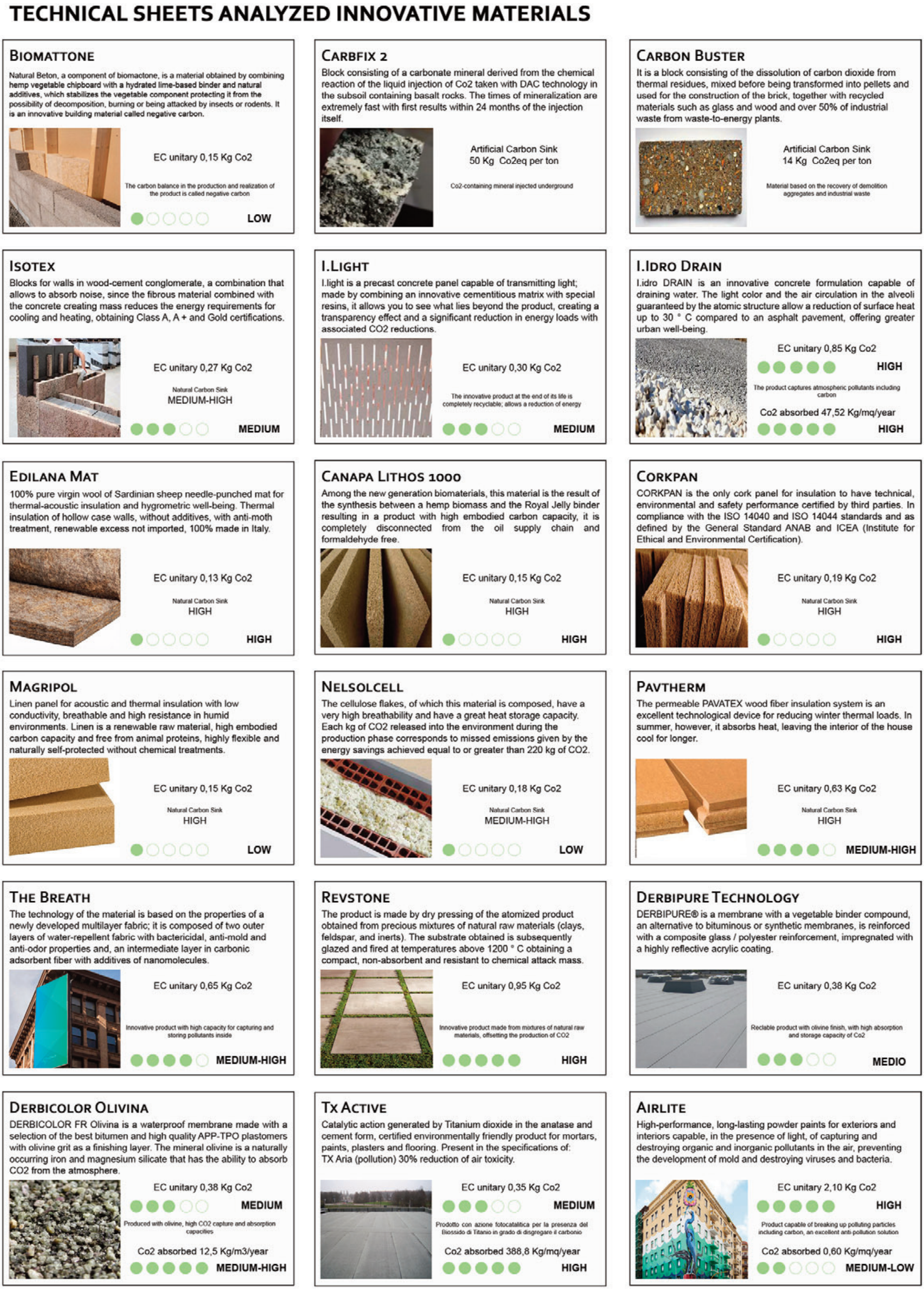


Fig. 7 | Summary data sheets of innovative materials analyzed (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

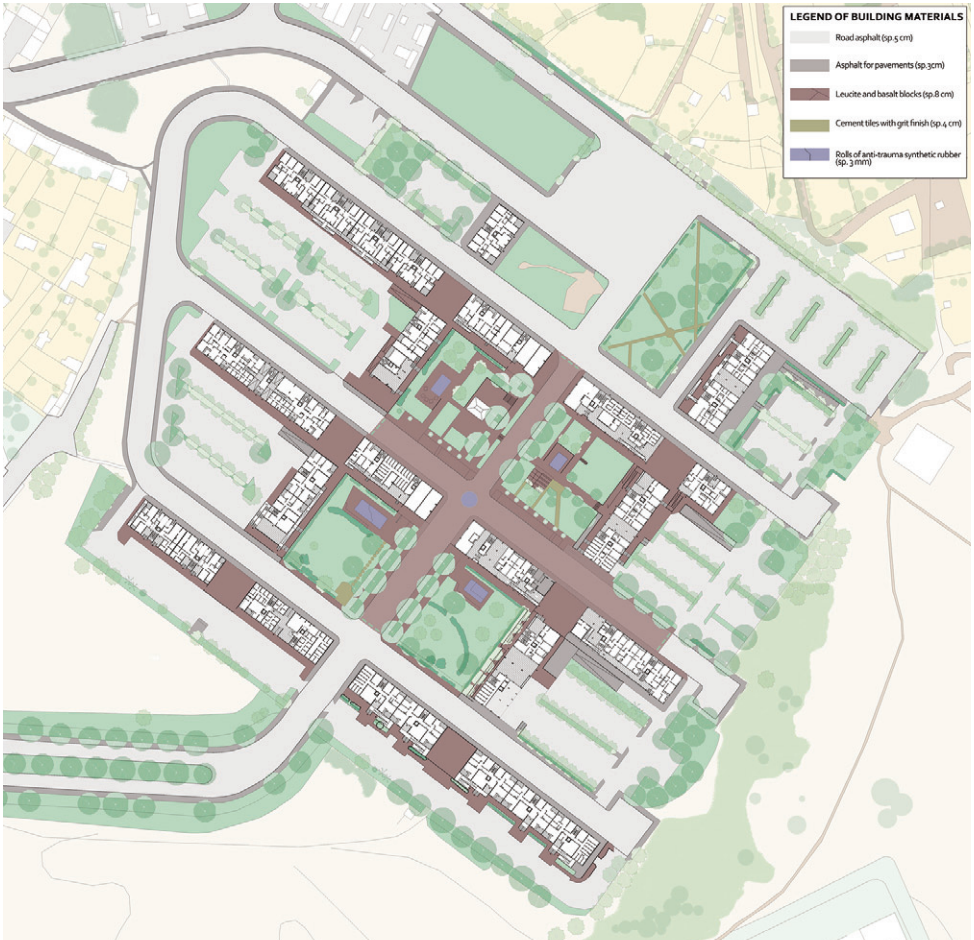


Fig. 8 | Option 1: San Basilio PdZ redevelopment scenario (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

tions of the FL2 Rome-Tivoli railway line are located within a 4 km radius. Pedestrian and bike mobility is also scanty. Given the meagre presence of local public transportation, private mobility by car and motor vehicles is quite widespread. Carbon emissions equal 3,578,130 $KgCO_2$eq/year.

The requalification, by means of 'grey' strategies, of the building stock and the open areas considered two options: the first with standard materials that are usually used in renovations; the second with materials that are highly innovative, carbon-free, or with emissions extremely reduced in all phases of production and processing, and in certain cases able to make an active contribution towards absorbing carbon from the atmosphere (Fig. 7). The proposed solutions are then compared with one another and

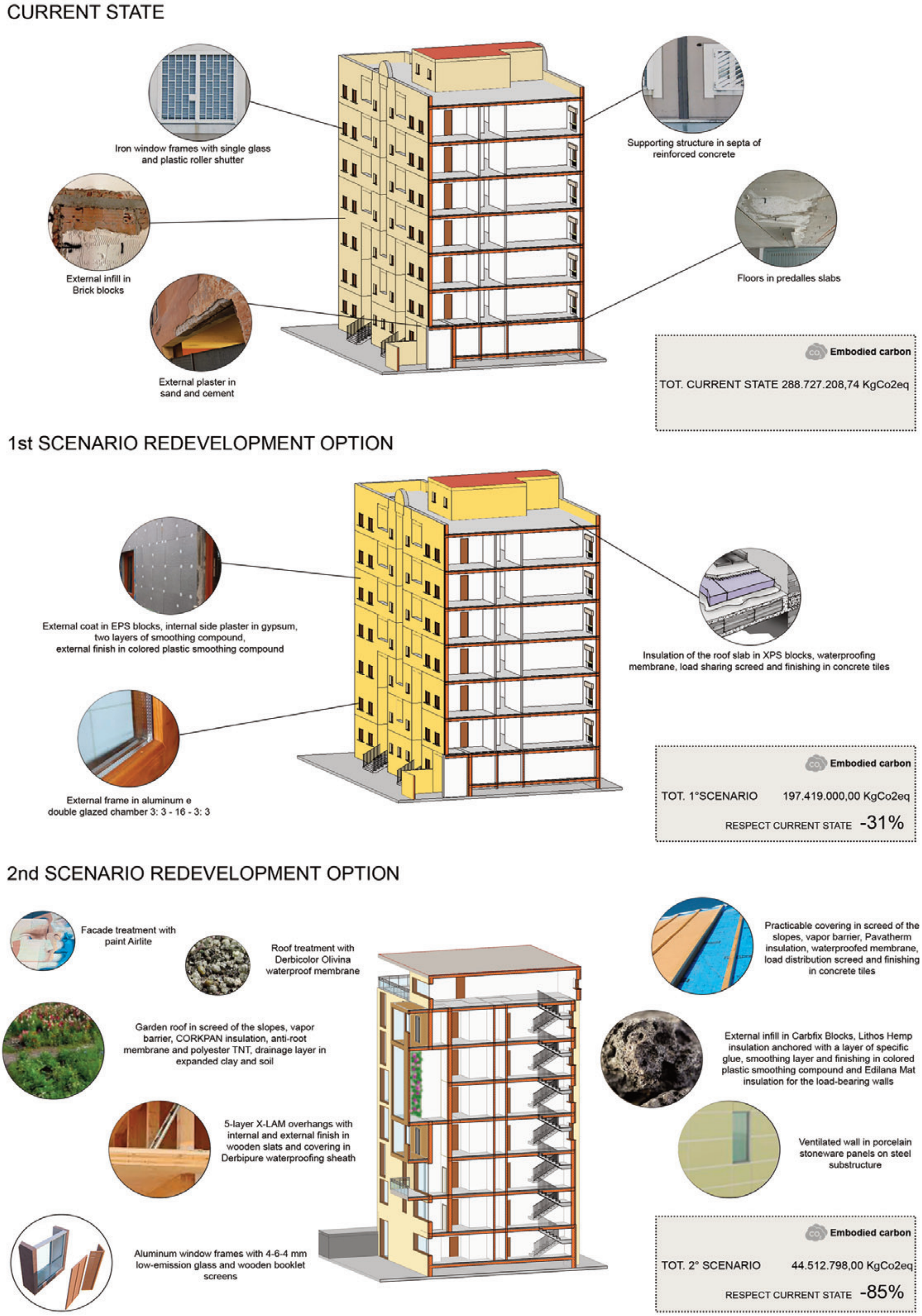


Fig. 9 | Graphical representation of the materials present in the current state and those introduced for the 1st and 2nd Redevelopment Scenarios (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

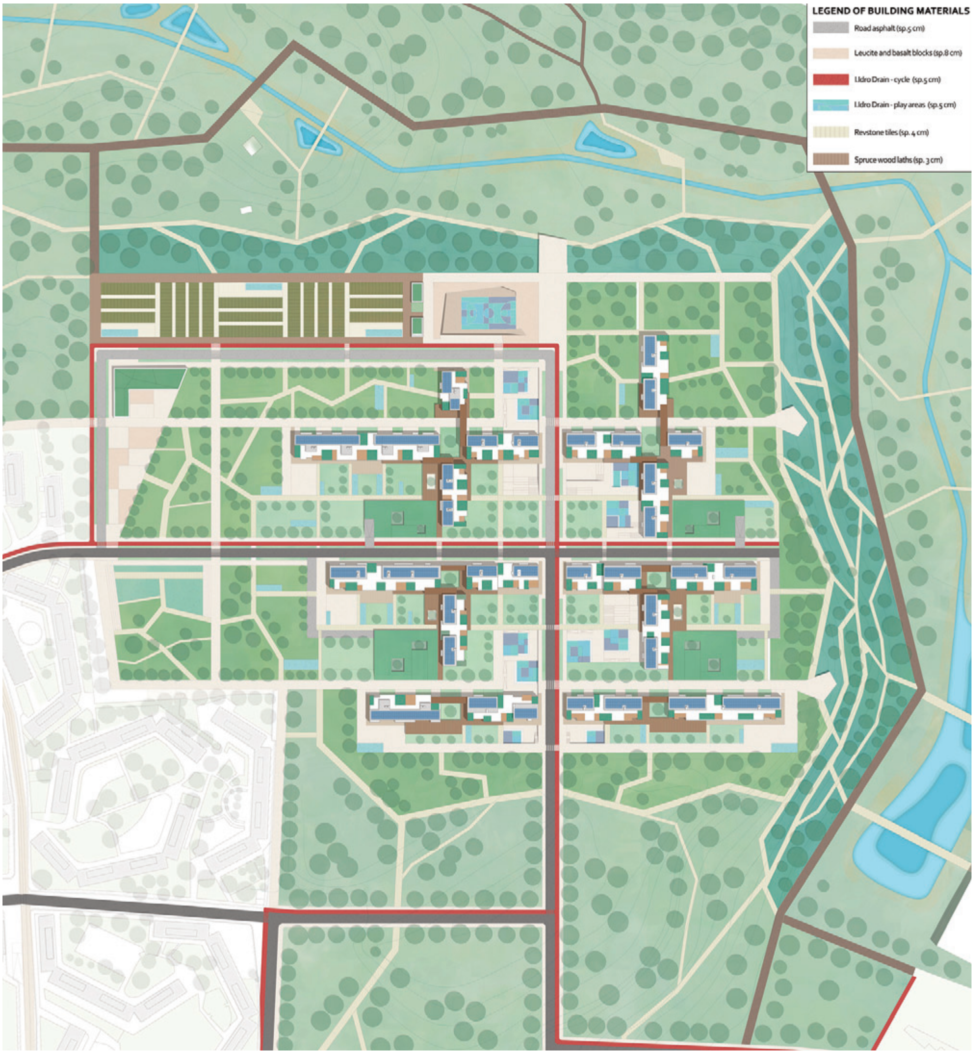


Fig. 10 | Option 2: San Basilio PdZ redevelopment scenario (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

with the actual situation. The first operation for the buildings' energy retrofitting and requalification is therefore based on maintaining the bearing structure in reinforced concrete, and on an application of such building materials as blocks and insulation for horizontal closures for the renovation of exterior envelopes and roofs, and the replacement of doors and windows, capable of increasing and improving thermal and energy performance. Emissions for energy consumption equal 1,013,187 $kgCO_2eq$/year, with embodied carbon equal to 54,849,066 $KgCO_2eq$.

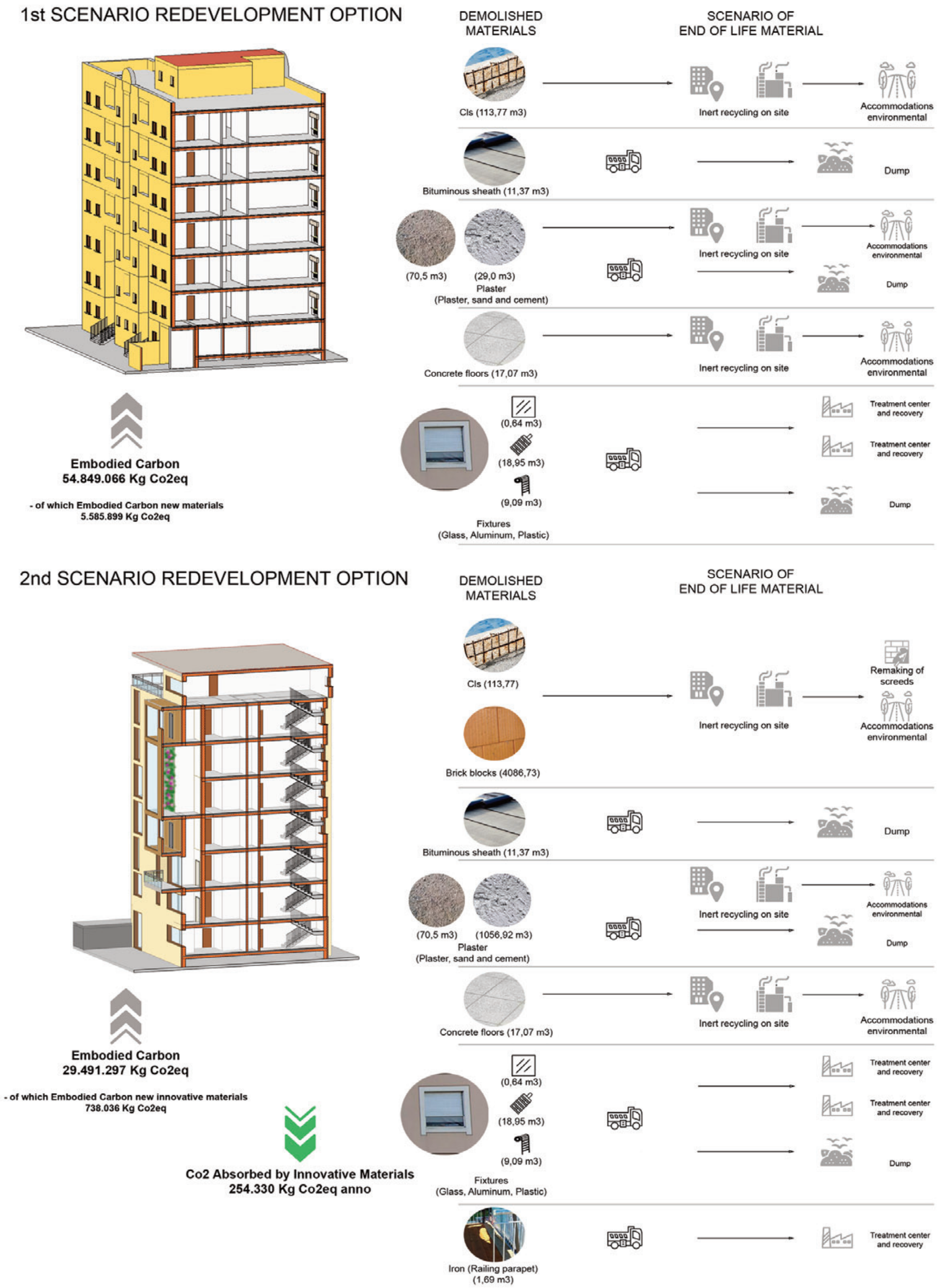


Fig. 11 | End-of-life prospectus of materials subject to demolition for the I and II Redevelopment Scenarios (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

As relates to open spaces, the working hypothesis calls for increasing the pedestrian areas by introducing slabs of basalt and leucite and new play areas (Fig. 8). For the materials subject to demolition like concrete, brick and plaster, onsite recovery is performed through the use of a mobile system for the processing of inert waste and the reuse of recycled aggregate for the renovation of carriageway road beds and environmental and landscape arrangements of the urban district, with a recovery percentage exceeding 90%[4], thus generating a savings of emissions due both to the lack of extraction and procurement of natural inert materials and to the transport of inert waste to the nearest recovery site (5,369 $KgCO_2eq$)[5]. For the materials originating from the replacement of doors and windows, like aluminium and glass, off-site management for additional use after industrial treatment (remanufacturing or recycling) is considered. However, the plaster and waterproofing membranes originating from the renovation of roofs are disposed of in a landfill. This requalification option calls for 142,570,013.88 $KgCO_2eq$ of total embodied carbon post-intervention.

The second requalification option calls for using innovative, experimental construction materials derived from processes of recycling urban and/or industrial solid waste, and completely recyclable natural fibres with extremely low unit embodied carbon. In specific terms, for the building stock, the interventions call for maintaining the existing bearing structure, with a redefinition of the vertical closures through the introduction of large glass surfaces with low-emission windows and doors, passive bioclimatic devices such as courtyards to the south, buffer space to the north, and overhanging bioclimatic greenhouses which result in increased volumes in keeping with the regulations in force, thereby improving the housings' adaptability and flexibility to achieve greater environmental comfort while reducing energy consumption for heating and cooling.

The exterior buffers were coat walls comprising natural insulation anchored onto massive elements in Carbfix blocks[6], derived from the capture of CO_2 in the atmosphere, using DAC (Direct Air Capture) technology, liquid injection into the subsoil consisting mainly of basaltic rocks and subsequent mineralization, and thus generating a building material with carbon storage capacity. The vertical exterior closures oriented to the west call for ventilated walls made with panels in stoneware on a steel substructure. The overhangs consisting of bioclimatic greenhouses are made with X-Lam 5 layers with the internal finish and treated wooded staves on the outside. The design of the horizontal closures, insulated with Corkpan slabs, calls for accessible roofs, garden roofs, and surfaces for introducing integrated photovoltaic panels with finishing in Derbicolor Olivina, with high CO_2 absorption capacity (embodied carbon: 29,491,298 $KgCO_2eq$; Fig. 9). In this regard, a CO_2 absorption equal to 254,330 $KgCO_2eq$/year, due to the use of innovative materials, is reported.

For this option, the project to redefine the open spaces calls for an increase in the permeable surfaces and a major reduction in vehicular traffic within the district, favouring soft mobility with the introduction of bike and pedestrian paths made with concrete, and I.Idro Drain with high absorption and storage capacity within its molecular structure of pollutant cells (Fig. 10). The design of leisure spaces and recreational areas to host open-air events and commercial activities considers the adoption of Revstone pavement, blocks of leucite and basalt, and pavement with tiles of photocatalytic cement. For the materials subject to demolition, a recovery percentage exceeding 88% is supposed, with in situ treatment of aggregates originating from concrete, brick, and plaster for the making of screed and exterior pavement, as well as, as relates to the remaining portion, for the urban district's scenic arrangement (embodied carbon: 15.021.500 KgCO_2eq; Fig. 11).

In the case in point, for the entire district, CO_2 emissions for heating, cooling, and lighting are set back to zero thanks to the emission savings equal to 607,058 Kg-CO_2eq/year due to the reduced energy requirement; these emissions are also offset by energy produced by renewable sources, embodied carbon equal to 44,512,798 Kg-CO_2eq. As regards the requalification of the water cycle, waste, and mobility, in this case as well two levels of improvement are considered. The highest-performing one refers to the EU indications at 2050, while the less substantial one is in an intermediate position between this and the current state (Fig. 12). This is discussed in greater detail as follows.

For the water cycle, the steps, in the case of the standard scenario, refer to the actual state, since normally no interventions in this regard are established; on the other hand, the innovative scenario provides for recovering the grey water and the rainwater, and for reducing the drinking water requirement thanks to the use of recovered water appropriately purified for the permitted uses (scenario 1: 63,485 KgCO_2eq/year; scenario 2: 16,262 KgCO_2eq/year).

For waste, the current state considers the waste produced for domestic activities and other activities in relation to the current users, for a separate collection percentage equal to 47% (achieved rate); having taken into account the emissions for the transport of waste in the neighbourhood that in scenario 1 waste production does not vary, the separate collection becomes 55% and the replacement of vehicles from Diesel to methane is planned; in scenario 2, the production of solid urban waste declines by 10% due to the inhabitants' greater awareness, the separate waste collection rate grows to 70%, and collection is optimized through the adoption of a pneumatic system integrated into the buildings and the adjacent exterior areas, with few collection points permitting a reduction of emissions for transport using methane vehicles (scenario 1: 3,244,161 KgCO_2eq/year; scenario 2: 1,946,306 KgCO_2eq/year).

For public mobility, the actual kilometres travelled yearly by the bus lines traversing the neighbourhood are taken into consideration, in accordance with the type of ve-

Next page

Fig. 12 | Summary results for Energy, Water, Waste and Mobility Networks Scenario I and II (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

WATER NETWORK

Residential and non-residential water needs

Residential drinking water
169.141 mc/y

Acqu Non-residential drinking water
195 mc/y

Total water requirement
169.336 mc/y
52.426 KgCo2/y

Water requirements for irrigation of green spaces

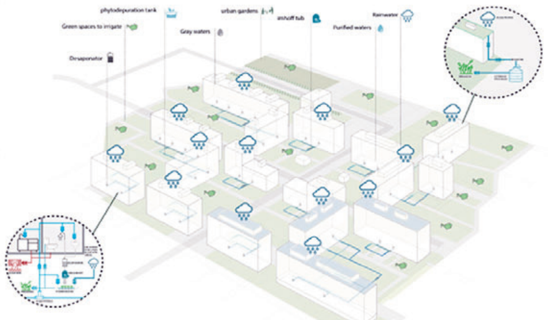
Pertaining green area (53.473 m2) per year is equal to 35.720 mc/y

11.058 KgCo2/y

Drinking water consumption balance of the res and non-project build-
TOT 205.056 mc/y

TOTAL CO2 CURRENT STATE

63.485 KgCo2/y



2nd PROJECT SCENARIO

Residential and non residential water needs

Residential drinking water thanks to the inclusion of gray and rainwater reuse systems equal to
35.128 mc/y

Non-residential drinking water thanks to the inclusion of gray and rainwater reuse systems equal to
1.384 mc/y

Total water requirement
36.512 mc/y
11.303 KgCo2/y

Emission of CO2 -78%

Water requirements for irrigation of green spaces

Verde di pertinenza (55.378 mq): 57.032 mc/y
tetto verde (1.152 mq): 230 mc/y
orti urbani (8.216 mq): 3.060 mc/y
totale: 60.323 mc/y

Final annual requirement with the recovery of rainwater and the surplus of water recovered from constructed wetlands
29.568 mc/y
4.958 KgCo2/y

Emission of CO2 -55%

Water requirements for irrigation of green spaces

Total residential and non residential gray water recovered	36.512 mc/y*
WC	18.025 mc/y
External uses	9.307 mc/y
Surplus	21.414 mc/y

Rainwater recovery

Total rainwater captured by flat roofs (10.393 mq), green roof (1.152 mq) and water square (1.772 mq)
9.341 mc/y

Drinking water consumption balance of the res and non-project build-
TOT 66.079 mc/y

	Emission of CO2
TOT CURRENT STATE	63.485 KgCo2/y
1° SCENARIO	63.485 KgCo2/y
2° SCENARIO	16.262 KgCo2/y

WASTE NETWORK

HOME USERS = 2317
NON-DOMESTIC USERS = 25

CURRENT STATE → 47% Raccolta differenziata

Municipal solid waste production
1.141.501 Kg/y

Separate collection rate in Rome
47%

Total urban waste collection in the district
677.505 Kg/y

Total undifferentiated RSU district
763.996 Kg/y

TOTAL CO2 EMISSIONS CURRENT STATE OF UNDIFFERENTIATED MUNICIPAL SOLID WASTE

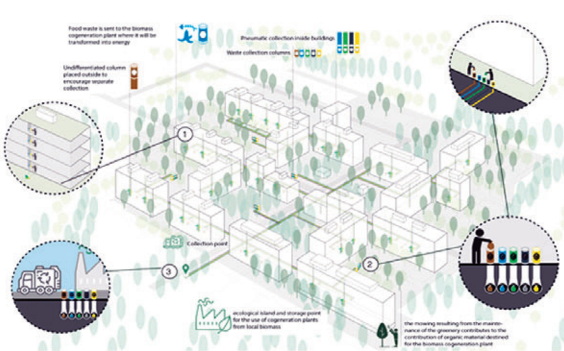
No. of harvest passages per week 7

Type of Vehicle: DIESEL

Current collection system on the road

Co2 emissions for the transport of waste in the neighborhood

TOTAL CO2 EMISSIONS STATE OF THE ART FOR MSW AND TRANSPORT TOT 4.941.547 KgCo2/y*



1st PROJECT SCENARIO	2nd PROJECT SCENARIO
HOME USERS = 2317	HOME USERS = 1604
NON-DOMESTIC USERS = 25	NON-DOMESTIC USERS = 738

2° SCENARIO DI PROGETTO → -10% / 70% Collection differentiated

	1st	2nd
Municipal solid waste production	1441501 Kg/y	1.297.351 Kg/y
Total urban waste collection in the district	792.826 Kg/y	908.146 Kg/a
Total undifferentiated RSU district	648.675 Kg/y	389.205 Kg/y
TOTAL CO2 EMISSIONS FOR UNDIFFERENTIATED RSU KgCo2/y	3.243.377 (Emission of CO2 -12%)	1.946.026* (Emission of CO2 -36%)

*The share of staff not considered because it is calculated in the context of biomass energy production

No. of harvest passages per week 5

Type of Vehicle: METHANE

Decrease in km traveled in the neighborhood through to an optimization of the collection

Co2 emissions for waste transport in the district KgCo2/y
784 (Emission of CO2 - 91%) 280 (Emission of CO2 -97%)

	Emission of CO2
TOT CURRENT STATE	3.880.351 KgCo2/y
1° SCENARIO	3.244.161 KgCo2/y
2° SCENARIO	16.262 KgCo2/y

NETWORK OF ENERGY AND BIOCLIMATICS (active and

CURRENT STATE	SCENARIO 1	SCENARIO2
Residential useful area 48.971 mq		Residential useful area 36.286 mq
Usable non-residential area 396 mq	48.971 mq	Usable non-residential area 13.081 mq

Residential Current state*

	Kwh/y	Emission of CO2	SCENARIO 2 Kwh/y	Emission of CO2
Common consumption and uses	349.112		144.487	
Consumption elect. + illum.	2.133.000		413.239	
Heating	10.959.504		165.165	
Cooling	308.517		7.460	
Domestic hot water	887.064		0	
TOT	14.647.197	3.577.843	730.327	268.246

*Assume standard basic situations based on the type of building

Non Residential Current state

	Kwh/y		SCENARIO 2 Kwh/y	
Consumption elect. + illum.	22.964		744.051	
Heating	67.320		204.214	
Cooling	10.996		17.916	
Domestic hot water	2.346		34.291	
TOT	102.960	28.335	1.000.472	338.812
TOT residential and non	14.750.157	3.606.178	1.730.799	607.058

Co2 emissions have been reduced by -83% Emission of CO2

SCENARIO 2

- Efficiency of the envelope and systems

Set of actions to increase the efficiency of the envelope and systems, energy-saving devices and appliances, LED lighting, lifts with energy recovery during braking

TOT 6.198.113 Kwh/y -58%

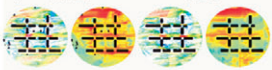
- Mitigation and microclimate

Reduction of cooling and heating needs

TOT 5.790.787 Kwh/y -61%

Summer

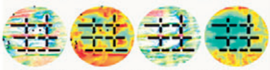
current state / scenario 2



Urban area temperature	Temperature mitigated	Ti	Savings energetic %
30	29	26	20%

Winter

current state / scenario 2



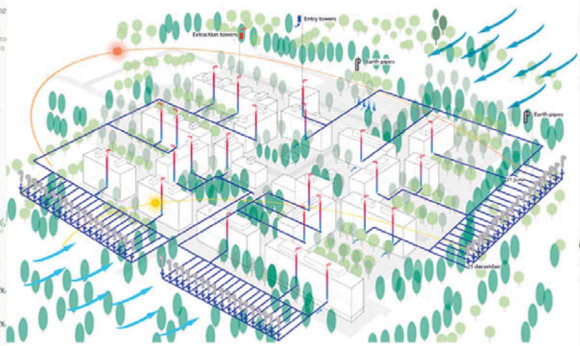
Urban area temperature	Temperature mitigated	Ti	Savings energetic %
10,1	11,9	20	2%

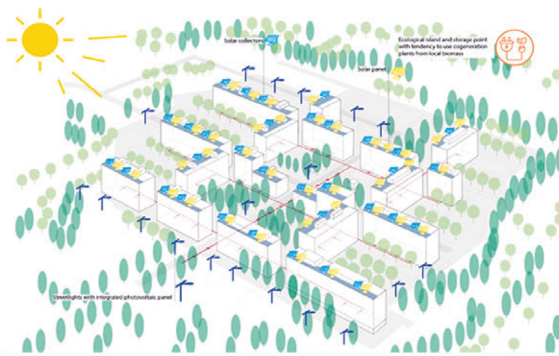
- Passive heating and cooling systems

TOT 2.883.188 Kwh/y -81%

- ICT optimization systems

TOT 1.730.799 Kwh/y -88%





	Emission of CO2
TOT CURRENT STATE	3.880.351 KgCo2/y
1° SCENARIO	3.244.161 KgCo2/y
2° SCENARIO	16.262 KgCo2/y

Public lighting

Kwh / a saved for public lighting with LED lamps with integrated photovoltaics: 47.025 Kwh/y

% di riduzione rispetto all'esistente -100%

- Energy from renewable sources

The district's energy demand of 1,730,799 Kwh/y is met by renewable energy sources

Photovoltaic 1.619.547 Kwh/y

% of the TOT energy requirement 94%

Solar Thermal 34.291 Kwh/y

% of the TOT energy requirement 2%

Biomass Produced by:

	Kg/y	Kwh/y
Green maintenance	244.380	1.153.474
Organic waste	276.308	2.686.323
TOT Biomass		3.839.797 Kwh/y

% of the TOT energy requirement 122%

\+ = 5.493.633 Kwh/y

TOT. 1° SCENARIO (efficiency of casings and systems) 1.013.187 KgCo2/y

TOT. 2° SCENARIO (energy coverage from renewable sources equal to 217%) 0,00 KgCo2/y

In summary

The final energy needs of the district (lighting and energy consumption of the buildings) are met thanks to renewable energy sources.

Total energy needs of the neighborhood	1.730.799 Kwh/y
Energy from renewable sources	5.493.633 Kwh/y
Surplus	3.762.834 Kwh/y

	Emission of CO2
TOT CURRENT STATE	3.606.168 KgCo2/y
1° SCENARIO (Intervention on passive bioclimatic envelopes and systems and ICT)	1.013.187 KgCo2/y
2° SCENARIO (Integration of renewable energy sources)	0 KgCo2/y

MOBILITY NETWORK

CURRENT STATE

Public transport

N ° lines	8
Average number of passes	56
Number of km traveled per year within the district	113.543 Km
Total CO2 emissions per year for public transport	136.991 KgCo2/y

(the type of power supply was considered on the basis of% of the bus fleet of the municipality of Rome)

Emission of CO2

CO2 emissions due to public transport 136.991 KgCO2/y

Trasporto privato

NB. The average car ownership per inhabitant in the current state is equal to 0.62

Car number	1.452
Average number of km traveled per year	9.805.396 Km

Emission of CO2

CO2 emissions due to cars 3.427.095 KgCO2/y

TOT CURRENT STATE : 3.578.130 KgCo2/y

TOTAL 1° SCENARIO:
- Public mobility (upgrading of bus lines) 2.635.032,58 KgCo2/y
- Private mobility (car ownership rate reduction) 51.154,61KgCo2/y

TOTAL 2° SCENARIO:

Public mobility increases by 20%

CO2 emissions due to public transport carried out with electric buses:
51.194 KgCO2/y

- Private mobility

Soft mobility incentive:

Cycle paths with a length of 2000 m

595 bike parking spaces

-76% reduction in level parking spaces compared to the project status

152 charging stations for electric cars (50% of the total)

In the 2nd Project Scenario, the use of private vehicles decreases by 19% according to the European average car ownership threshold per inhabitant (0.5) compared to the current 0.62 in Rome

CO2 emissions due to electric and hybrid mobility of the private vehicle of the project
1.320.696 KgCO2/y

	Emission of CO2
TOT CURRENT STATE	3.578.130 KgCo2/y
1° SCENARIO	2.686.187 KgCo2/y
2° SCENARIO	1.019.574 KgCo2/y

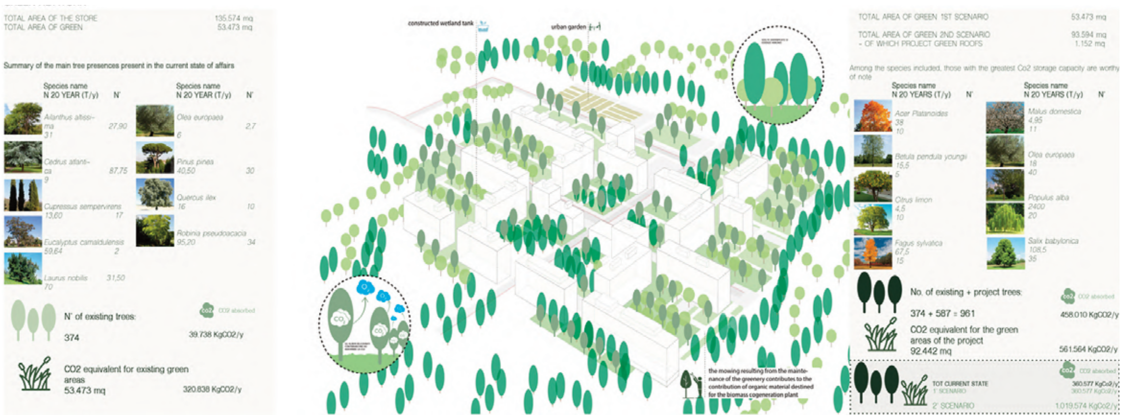
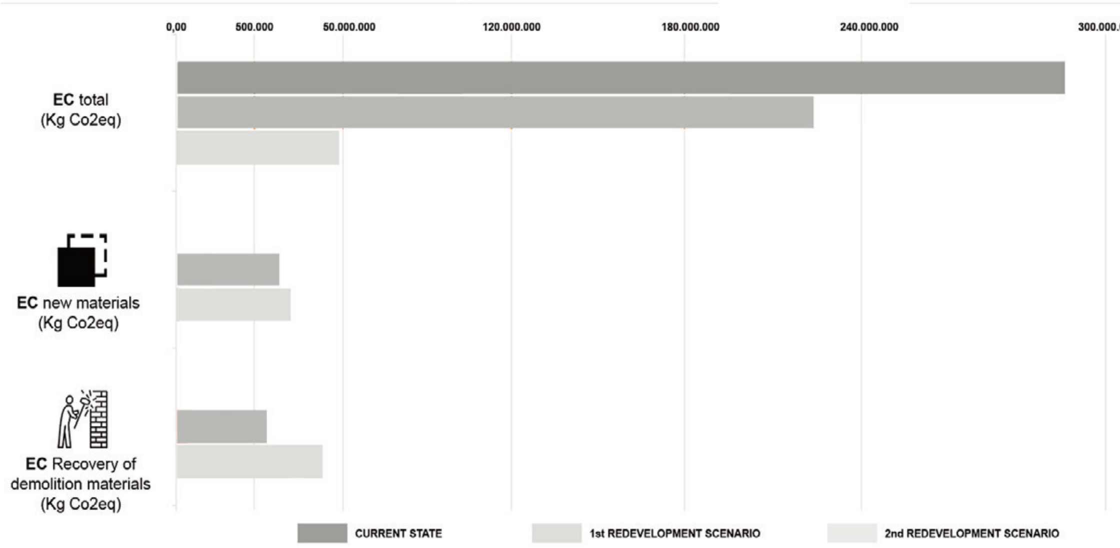


Fig. 13 | Summary results for Scenario I and II of the Green Network (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

hicles provided, and for private transport, consideration is made of the average motor vehicle ownership rate (62%) with the types of fuel that are present, and average yearly distance travelled. As the first hypothesis, the project supposes a 20% increase in public transport becoming entirely electric, against a reduction in the ownership index, as in the European average (50%) which alone brings a benefit in terms of emissions, a 30% increase in electric cars in circulation, 30% of hybrids, the elimination of Diesel, the containment of petrol-fuelled vehicles to 33% (from 54%), and the confirmation of cars fuelled by LPG (7%) and methane (1%). In the second scenario, only private mobility varies, with electric going on to 50%, hybrid to 43%, LPG (7%), and methane (1%) and, having eliminated petrol-fuelled cars, soft mobility is incentivized, with bike paths and more extensive pedestrian area, and the 76% reduction of street-level parking (scenario 1: 1,810,899 KgCO_2eq/year; scenario 2: 1,326,126 KgCO_2eq/year).

The experimentation considers, in the first hypothesis, the invariance of plant cover, amounting to 374 trees, and in the second one the introduction of 587 new trees of such species as ‘Acer campestre’, ‘Ginkgo biloba’, ‘Populus alba’, ‘Salix babylonica’, and ‘Ulmus minor’, with high capacities for environmental mitigation according to an absorption equal to 146,910 KgCo_2eq/year, and the strengthening of existing and autochthonous ones like ‘Fagus sylvatica’, ‘Laurus nobilis’, ‘Malus domestica’, ‘Olea europaea’, and ‘Pinus pinea’, recovering the degraded areas. The green area also increases, from 39% to 68%, and 1,152 sqm of green roofs are installed (scenario 1: -360.577 KgCO_2eq/year; scenario 2: -1.019.574 KgCO_2eq/year; Fig. 13).

The greenery calculation does not take account of private greenery, which toward this end does not have great weight, but is still an element linked to private behaviours that ought, in any case, to be spurred towards sustainability, because without them the already difficult challenge becomes daunting.



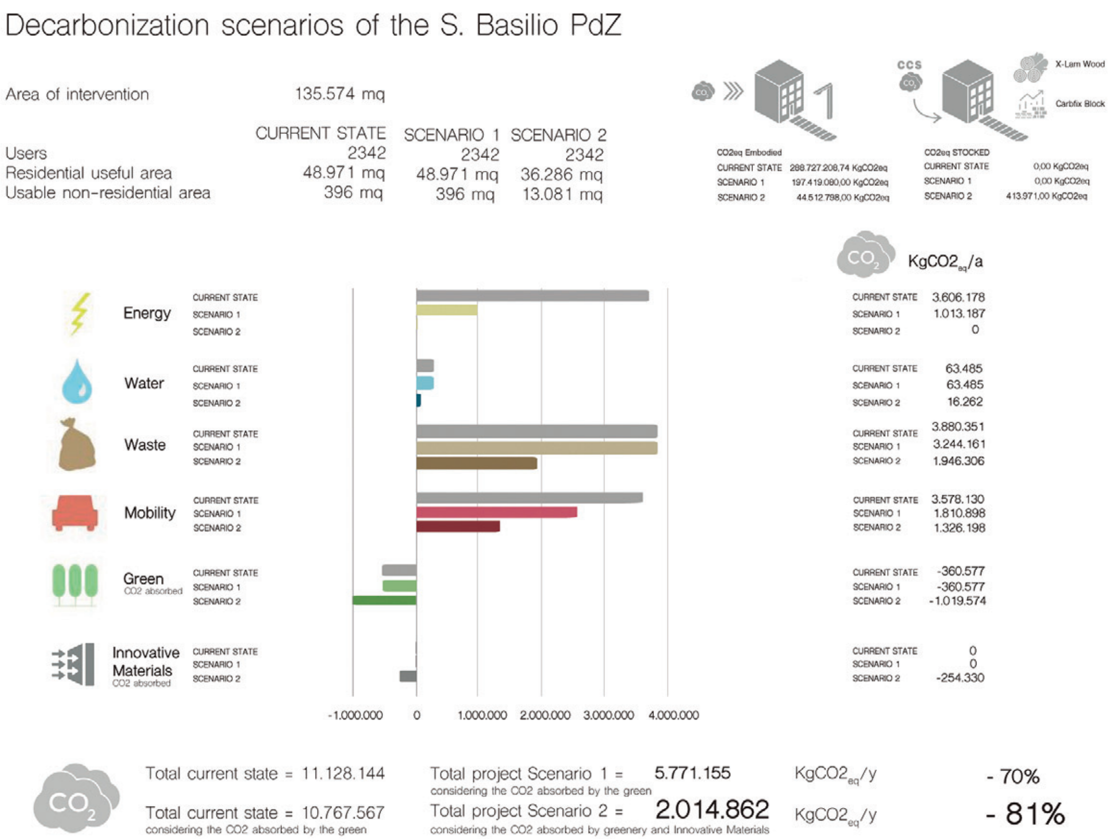


Fig. 14 | Final balance of total embodied carbon, new materials introduced and and recovered from demolition materials, according to the current state, I and II Redevelopment Scenarios (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

Fig. 15 | Final CO_2 emissions budget with district decarbonization scenarios (credit: F. Tucci, P. Altamura, V. Cecafosso, M. Giampaoletti, 2022).

Discussion of the results | The application of the methodological approach and the strategic lines set out during the experimentation allows the impacts and effects of the planning choices to be assessed in terms of performance of unit embodied carbon, and of absorption and storage of carbon from the atmosphere. A useful summary framework for plant selection in urban forestry/reforestation has also been defined. In terms of net emissions, the neighbourhood's general situation in the first hypothesis involves a 46.4% reduction in emissions, and in the second hypothesis an 81.3% reduction in comparison with the current state; their difference marks the advances achieved due to the high-performing materials, the broad use of passive solutions, and increased greenery (Fig. 14). For the individual sectors, the emissions generated by energy consumption are reduced by 72% in the first hypothesis and are reset to zero in the second due to the mentioned interventions and the progressive use of renewable sources; water in the first hypothesis records no variations, and in the second declines by 74%; waste declines in the two scenarios, by 16% and 50% respectively, and mobility by 49% and 63%. The strategy of the increasing tree and shrub stocks with the introduction of new tree species, autochthonous and with a capacity for environmental mitigation, led to a 183% increase in carbon absorption, and as for residual emissions absorbs 31%, while 8% is what is absorbed by the use of 'grey' materials (Fig. 15).

The CO_2 storage capacity relates only to the second hypothesis that was made, and amounts to 413,971 $KgCO_2eq$, a quantity linked to the use of biologically-based material for requalification (wood) and the use of technologically emerging technological DAC solutions derived from the mineralization of CO_2 through industrial processes. In terms of embodied carbon, compared to the construction in the de facto situation, the examined scenarios lead to a 32% reduction in the first case and a 77% one in the second. The application of 'green' and 'grey' solutions for decarbonization in the area in question, therefore, combines the active capacity to absorb CO_2 from the atmosphere during its use phase on the one hand, with the passive CO_2 storage capacity in the built environment, understood as a Carbon Sink, on the other. These choices, combined with the improvement of environmental parameters and microclimate well-being through the strengthening of tree and shrub stocks, increase the capacity for environmental mitigation, guaranteeing more liveable, functional, and healthy spaces for residents.

Research conclusions and future outlooks | The research emphasized how the struggle against climate change and the challenge of remaining within the temperature increase limit set by scientists under penalty of imperilling System Earth, are difficult and complicated, having considered that the time to intervene has shortened, and the commitments taken on by several countries are currently only partially maintained, and not everyone feels involved. Moreover, from the methodological standpoint, it emphasized the complexity of the methods for estimating emissions, linked both the variability of the parameters to be considered, and to the dearth of reliable and relevant databases, especially on a national level. However, important confirmation emerges with reference to the potential contribution that can come from intervention on the built environment and from the effectiveness of the passive technologies that can be applied to bring buildings, districts, and cities to grapple with this problem. In any event, the criticality remains of having to extend the requalification intervention, which should affect a considerable part of the building stock and existing construction.

The establishment of a ‘district grid’ for the management of the various investigation settings (mobility, waste, water, energy) might offer a considerable reduction of CO_2 emissions derived from an improvement of man-made processes, combined with careful design choices aimed at the scenic requalification of open spaces, by increasing permeable surfaces, with the planting of tree and shrub species with a high capacity for environmental mitigation. These urban greening strategies, defined as best practices in the context of infrastructure, are highly incentivized at present thanks also to the sustaining of economic plans and programmes diversified in form and content in each Member State, therefore defining potential positive impacts in cultural and socioeconomic terms in the areas subject to regeneration.

Currently, however, the adoption and use of innovative materials, with the storage capacity, absorption of carbon in the atmosphere, and reduced unit embodied carbon, is limited due to the still experimental nature of some of the materials analysed in this paper. Although the use of materials and insulation derived from natural, recycled, and recyclable resources, is acquiring greater strength in the choices by the actors in the supply chain, aimed at planning that is adaptive and with low energy consumption, product costs – in relation to the capacity to absorb carbon from the atmosphere, especially for solutions like painting and photocatalytic treatments – are currently high. Moreover, doubts remain as to the effect that titanium dioxide, a catalyst in the photocatalysis process, might have on human health, given the recent proposal by European Law and by ISPRA to classify TiO_2 as ‘suspected of causing cancer through the inhalation route’.[7]

The research prospects, then, on the one hand, relate to experimentation on the materials and their gradual improvement in terms of both ecology and bio-toxicity, as well as the optimization of performance in capturing climate-change emissions, and on the other to perfecting verification and calculation methodologies through the construction of databases specific to the national context.

Notes

1) This paper is the product of two research efforts carried out in continuity at ‘Sapienza’ University of Rome, Department of Planning, Design, Technology of Architecture. The first was the PRIN (Progetto di Rilevante Interesse Nazionale – project of overriding national interest) Research titled ‘TECH-START – Key Enabling Technologies and Smart Environment in the Age of Green Economy – Convergent Innovations in the Open Space/Building System for Climate Mitigation’ (2019-2021), with specific reference to the work by the ‘Sapienza’ University of Rome operating unit, Principal

Investigator Prof. F. Tucci. The second is the Research financed by ‘Sapienza University’ titled ‘Climate-Pandemic-Proof Design: strategie, misure, sistemi tecnologici per la mitigazione climatica e la neutralità carbonica post-Covid’ (2021), Principal Investigator Prof. Fabrizio Tucci. The working group that worked specifically on the aspects present in this paper, again under the scientific responsibility of F. Tucci, is composed of the following: Arch. PhD P. Altamura, Arch. PhD V. Cecafosso, Arch. PhD G. Turchetti, Arch. PhD M. Giampaoletti; Collaborators: Arch. F. Nava, Arch. M. M. Pani, Arch. G. Romano, Arch. V. Tulelli, Arch. C. Dalsasso, Arch. L. Giannini, Arch. I. Fabiani, Arch. G. Trifoglio, and Arch. M. Vadalà. The images were conceived and developed by the article’s authors with contributions by: L. Giannini for Figures 1, 2, 3, 5, 6, and 10; L. Giannini with processing by V. Cecafosso and M. Giampaoletti for Figures 4, 7, 8, 9, 11, 12, 13, 14, and 15.

2) The following were used: Inventory of Carbon and Energy (ICE database), available at circularecology.com/embodied-carbon-footprint-database.html [Accessed 27 August 2021], LCA technical data sheets and studies on specific products.

3) CO_2 absorption capacity of tree and shrub species, done in accordance with consultation and subsequent processing of results of research carried out by CNR’s Istituto di Biometeorologia under the Regional Plan for Environmental Air Quality of the Region of Tuscany (2018).

4) Minimum recycled content according to the Italian Ministerial Decree of 11 October 17 (Minimum mandatory environmental criteria of the National Action Plan for Green Public Procurement for construction) is equal to 70%. For more information, see: anit.it/wp-content/uploads/2017/11/DM-11-ottobre-2017.pdf [Accessed 14 August 2022].

5) Estimate calculated taking account of the waste aggregate recovery installation closest to the intervention area (25 Km), analysing CO_2 emissions/Km and the standard load of a truck for the transport of construction-related aggregate waste.

6) For more information on The Carbfix Project (2020), see: carbfix.com/ [Accessed 27 July 2022].

7) For more information, see: isprambiente.gov.it/it/attivita/crisi-emergenze-dann-old/rischio-sostanze-chimiche-reach-prodotti-fitosanitari/news-in-evidenza/proposta-di-classificazione-per-il-biossido-di-titanio-tio2-come-sospetto-cancerogeno [Accessed 27 July 2022].

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THE PROMOTING OF SHORT SUPPLY CHAIN WOOD PRODUCTS PROTECTING BIODIVERSITY

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ABSTRACT
The Italian forest area, about 40% of our territory, represents a resource that requires sustainable management plans focused on the protection of biodiversity, with timber for the construction sector coming as much as possible from native wood species, exploiting the opportunities offered by the forest bio-economy. The paper starts from the national wood supply/demand gap and presents a survey of local species potentially usable for Vertical Perimeter Walls with exposed wood. Analysis and evaluation of the case study solutions adopted in buildings that foresaw the use of short supply chain species for the external and internal cladding layers in line with sustainability criteria and functional and architectural characterisation (Availability, Recyclability, Integration Maintainability and Appearance). The structure of a multi-criteria analysis to apply to them, providing relevant references for developing a 'repertoire of technical solutions' of Vertical Perimeter Walls, as a tool for making sustainable design choices.

KEYWORDS
forest bio-economy, biodiversity, wood technology, short supply chain products, vertical perimeter walls

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The scientific community has been studying the anthropogenic impact on biodiversity and natural systems for decades and, particularly in recent years, is increasingly mobilising to propose solutions to reverse the biodiversity loss curve (WWF, 2020). The protection of ecosystems and biodiversity plays a crucial role in implementing the European sustainable growth policy in the context of the European Green Deal (European Commission, 2019). The European strategy fits into the global context outlined by the 2030 Agenda for Sustainable Development (UN, 2015) whereby the achievement of environmental (biosphere) goals is considered a necessary condition to achieve all others (Folke et alii, 2016). The new European Biodiversity Strategy 2030 Bringing Nature Back into Our Lives (European Commission, 2020), stems from these considerations, a highly renewed instrument whose pillars pay particular attention on areas with high biodiversity potential. The forests, as carbon-rich ecosystems, with a commitment to increase their extent, quality and resilience by 2030, respecting ecological conditions consistent with native woody flora and local natural vegetation potential. Enhancing timber supply chains and incorporating these resources into the bio-economy ensure economic growth and the satisfaction of social needs through the sustainable use of renewable biological resources (European Commission, 2012).

Forests, wood and other services and products from forest ecosystems (forest bioeconomy), recognising them as fundamental tools for mitigating global climate change, represent an essential resource in our country. Italians' forests are among the richest in biodiversity in Europe; they have recently become part of a Sustainable Forest Management (SFM) process and a crucial ecological 'rewilding' phase, leading to the doubling of our forest area to about 12 million hectares, or almost 40% of the national territory. As a result, the mitigation role of Italian forest ecosystems has increased positively, storing about 4,5 Gt of CO_2, and absorbing 12% of all Italian emissions annually (Comitato Capitale Naturale, 2021). Despite occupying 40% of the national territory, timber harvesting is far below the EU average and far below the growth and ecological productivity of our forests. They contribute only 0,08% of GDP, a figure that only partly reflects what our forests can be used for, considering the enormous potential of wood utilisation in the construction sector (Osservatorio per il Capitale Naturale, 2020).

National forest planning, although virtuous, shows a timber harvest for the construction sector that is very low compared to European standards. The result is a gap between the import and export of timber products for structural and non-structural use, especially for the timber construction market, which maintains a growing trend[1] also thanks to a more widespread and consolidated technical knowledge (Ferrante, 2008), but which goes along with the prevalent use of fir. This sector is still too much characterised by spruce products from the sometimes indiscriminate use of central European forests.

Promoting a short supply chain (Scarascia Mugnozza et alii, 2019), using only the species that are most widespread in our country, might contribute to activating virtuous

Fig. 1 | Pizzolato Winery in Villorba (Italy), designed by Made Associati (2013-2016). In this project, the use of beech wood for the building's cladding and external flooring was experimented with in an ecological way. This is PEFC-certified wood from the nearby Cansiglio beech forests. The wood was left natural for the floors and furniture (about 1,500 square metres), while for the exterior cladding it underwent a thermo-baking treatment that makes it more resistant to atmospheric agents, without precluding its recycling at the end of its life (credit: madeassociati.it, 2019).

Fig. 2 | Cetic Offices in Châlon sur Saône (France), designed by Atelier Architecture (1972). For the external cladding of the building, strips of heat-treated local poplar were used to improve durability and give the grey colour, a guarantee of colour uniformity in anticipation of ageing (credit: le-gallee.fr, 2019).

mechanisms for the forest-timber supply chain in view of a circular bio-economy (Hetemäki et alii, 2017), generating economic resources for local territories and allowing the establishment of wood industry clusters, business networks and consortia, while responding to the environmental emergency with actions appropriate to the ecological transition. Detailed forestry planning capable of enhancing our utilisation of wood for non-structural use is in line with the protection of natural capital, ecosystems and biodiversity, as well as promoting excessive forest cover monitoring (Fares et alii, 2015) as one of the causes of the fragility of territories towards extreme climatic events.

This paper intends to present the results of the research funded by the PRIN 2015 entitled 'The short supply chain in the biomass-wood supply chain: supply, traceability, certification and carbon sequestration – Innovations for green building and energy efficiency' (Scarascia Mugnozza et alii, 2021), which promoted the use of short supply chain species for the revitalisation of local production through the multidisciplinary contributions of the fields of forest ecology and silviculture together with those of structural engineering and architectural technology. It shows the potential of using 'exposed wood' in buildings (Figg. 1, 2), In the study of tools to aid sustainable design choices and in the proposal of a repertoire of technical solutions for the finishing of Vertical Perimeter Walls (VPWs) made of wood or wood derivatives, the research group of the Sapienza University of Rome uses products made of short supply chain species.

The focus on VPW as a symbiotic integration between natural materials/products and the building identifies a field of investigation to illustrate application possibilities and criticalities of wood products. A dimensional development, a substantial part of the building, for the functions performed, highlights the technical issues related to durability (Paoloni, Ferrante and Villani, 2018), as well as represent the principal architectural characterisation of the building. For this purpose, VPW solutions with wood cladding applied in many recent buildings were assessed with respect to several significant criteria of quality in terms of sustainability (Findability of the wood species, Recyclability) and functional as well as architectural characterisation of the building (Integration, Maintainability, Appearance).

Subsequently, for an objective comparison of the solutions themselves, we performed a multi-criteria evaluation to weigh the quality of the technical solutions adopted with respect to each criterion and as a whole. The assessment adopted for the case studies has allowed the structuring of a repertoire of technical solutions with reference to the external/internal cladding of VPW, to promote the innovative use of products obtained from the processing of short supply chain species (beech for interiors and chestnut, poplar, local pine for exteriors) to illustrate the performance of the different functional models, the material compatibility between components, their durability and recyclability. Considering that each design context requires to relate to specific locational, functional, performance and architectural factors, the repertory intends to provide clients, designers and operators in the sector with an initial structured set of technical solutions for the choice of VPW cladding and the possible use of local woods of proven technical and morphological quality.

Short supply chain and quality assessment of technical solutions for Vertical Perimeter Walls: case studies | To promote innovative and rational use of wood species from the local forest heritage[2], in addition to supporting the eco-systemic conversion of our construction sector, it was first necessary to proceed with a survey of the most widespread wood species on the national territory[3], and analyse their main characteristics for use in wall cladding components. During the first stage of the research, properties and characteristics of native species such as chestnut, beech, local pine and poplar were defined, adopted in many case studies analysed, their respective territorial diffusion, and their possible use for VPW 'visible' claddings (Tab. 1).

Given this analysis, the second stage concerned the search for architectural constructions requiring interior and/or exterior cladding layers to use the identified species, with particular emphasis on those examples where the woods had a local provenance. To highlight the expressive possibilities of the application of wood claddings, the case

SPECIES	SPREAD	FEATURES	USES IN EXTERNAL WALLS
'Chestunt'	It is found along the entire Alpine arc up to altitudes of 800-900 m above sea level, along the Apennine ridge as far as Calabria, in Sicily on the slopes of Mount Etna and in Sardinia	A tree species native to Mediterranean countries, it can reach a height of 10/30 m Mass density: 530kg/m^3 Durability: class 2 Hardness: 18 N/mm^2 Use: class 3 (outdoor, not in contact with the ground) Shrinkage: medium-low Dimensional stability: good	Due to its durability and resistance to humidity, it is very well suited for both exterior and interior cladding elements, mainly used in planks and beads, without the need for special treatments
'Beech'	It is among the most widespread species in Italy. Beech is most widespread in the regions of Abruzzo, Emilia Romagna and Liguria High forests are more widespread in the south, while in the north coppices, largely initiated or in the process of being initiated into tall trees, account for almost all over-grounds	In closed stands, with a high crown, the beech reaches up to 35 m in height Mass density: 680kg/m^3 Durability: class 5 Hardness: 34 N/mm^2 Use: class 2 (indoors or under cover) Shrinkage: marked Dimensional stability: low	Its use in solid wood is found exclusively for interior cladding. More widespread is its use in plywood panels for wall panelling, furniture If suitably treated (thermo-treated) it can also perform well in exterior applications. Surface treatments allow for numerous varieties of colouring
'Larch Pine'	It is most widespread on the Silan Plateau in Calabria, but large quantities can also be found in Sicily and Corsica	An evergreen tree, it usually reaches a height of 20-25 m, and only occasionally can grow to 40 m Mass density: 760kg/m^3 Durability: class 4-5 Hardness: 25 N/mm^2 Use: class 4 (outdoor) Shrinkage: Medium-low Dimensional stability: medium-low	It is a difficult wood to process It is used in structural elements (especially glulam and CLT) in reconstituted particle boards Some innovative production lines offer cladding elements (staves, beads, boards) made of charred pine wood in a single ply (18-20 mm) or 3-ply (20-25 mm)
'Poplar'	It is very widespread in the Po Valley area, but also in Lombardy, Piedmont, Veneto and Friuli Venezia Giulia	Poplars range in height from 15 to 30 metres and more, with trunks that can exceed 2.5 m in circumference; very workable softwood Mass density: 480Kg/m^3 Durability: class 5 Hardness: 11 N/mm^2 Use: class 1 (interior, dry) Shrinkage: low Dimensional stability: good	Its widespread use can be found in the production of plywood and multilayer panels for interior cladding. Due to thermo-treatment at temperatures between 180 °C and 200 °C, its ability to be exposed outdoors can increase significantly. For interior cladding, poplar bark is also widely used

study selection process drove the desire to illustrate the morphological-formal aspects as well as the technical and functional characteristics of the cladding systems for VPWs, highlighting how the solutions employed envisaged the use of certain wood species within the scope of their peculiar features and/or criticalities (cf. use of woods with low durability levels and the need for prior treatment to be exposed outdoors). In many cases, great attention is paid to the use of wood from neighbouring supplies, alongside a design development of technical elements coordinated with local wallcovering manufacturers.

The selected projects include different climatic zones, where thermal and hygrometric variations, atmospheric precipitation and winds were studied as the principle agents to consider the design of VPW solutions involving exposed wood. Various uses were also examined to demonstrate the versatility of the claddings (Figg. 3-5), with a particular interest in public works, in view of the incentive of the NAP GPP – National Action Plan on Green Public Procurement (MATTM, 2007), which has given rise to many initiatives in the field of timber architecture. In particular, the collection activity concerned approximately 50 works intended for various functions (schools, health facilities, office buildings, collective residences, hotels, museum facilities, etc.), built in the last 10 to 15 years, considering this a sufficiently large period in which to assess the durability of the claddings applied.

To obtain a comparison as homogeneous as possible between the various cases examined, we set up a structured data collection method that, starting from general information (so as to allow for the correct framing of the set of design choices based on the climatic zone and context conditions), goes on to investigate the specific construction solutions adopted for the VPWs and the technical characteristics of the individual wood and/or wood-derived components making up the organisation of the functional layers. The data collection on the case studies was necessary to ‘abstract’ the properties and characteristics that enabled the realisation of the timber structures and to appreciate the technical choices through the systematisation of quality indicators.

In the third phase of the research, we then defined some qualitative criteria to evaluate the solutions to highlight the possibilities of using timber wall claddings. These Criteria emphasised different aspects of the performance response of wood applications in cladding solutions: a) environmental and economic sustainability with Recoverability and Recyclability criteria; b) functional and architectural character of the building with the criteria of Maintainability, Integration and Appearance.

More specifically, Availability is related to the raw material and the products to use in the construction solutions (first, second and subsequent processing products, distribution systems, etc.), as well as local know-how and technical capacities for installation, maintenance, recovery and end-of-life. Recyclability is less to do with the raw

Tab. 1 | Characteristics of the main Italian wood species potentially usable in external wall solutions (source: National Inventory of Forests and Forest Carbon Sinks; credit: Research Group elaboration, 2020).

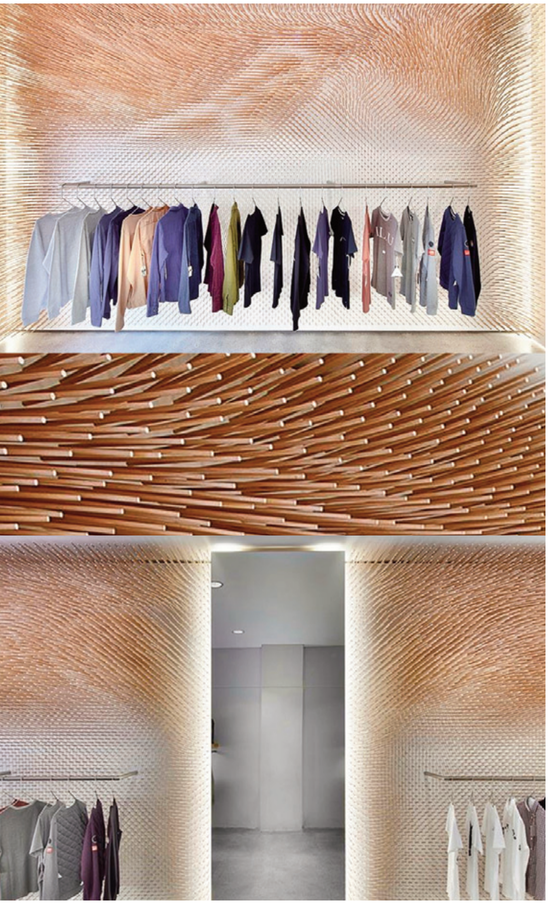


Fig. 3 | New Damiani Holz headquarters in Bressanone (Italy), designed by Modus Architects (2011). External cladding in Kerto elements fixed on an OSB layer and shaped using CNC techniques; for the interiors, some rooms were designed to leave the XLam panels of the load-bearing structure visible, working with milling techniques (credit: A. Merotto, 2020).

Fig. 4 | Norwegian Wild Reindeer Centre Pavilion, designed by Snøhetta, 2011. Part of the exterior and interior cladding is pine. The exteriors were treated with pine tar, while the interior wood was oiled; Hardangerfjord shipbuilders made organic shapes from digital 3D models interoperable with milling machine software; the connections between the elements are all-wood with pegs (source: snohetta.com, 2018).

Fig. 5 | MRQT Boutique in Stuttgart (Germany), designed by Studio Rok (2013). Interior cladding made from a texture of 22,000 beech wood sticks; the holes on the backing layer were made with CNC machines defining the precise direction of each stick; the extension of the wooden sticks in various directions and of different lengths create a fluid form (source: rok-office.com, 2018).

material wood, which is characterised by many recycling possibilities, than with how the components of functional layers are connected and how treatments of layers visible on the outside might compromise disassembly and reuse. Serviceability, relating to Life Cycle Thinking logic, refers to the durability and reliability of wood products, to the use of solutions already in the design phase, which have foreseen the performance efficiency and possible maintenance activities (treatments, replacement, etc.). Integration relates to connections of the functional layers of the VPW and links between them and other technical elements of the building system (horizontal closures, fixtures, false ceilings, etc.), structural and plant engineering elements, with reference to the inspectability of the parts; integrability with furniture and/or equipment elements (fixed furniture, wooden panelling, etc.) is considered for interior claddings. The criteria of appearance for VPW claddings embrace a broader spectrum of characteristics referring to the peculiar colours of the chosen wood species, dimensional stability, and the ability to maintain the required performance over time, and also considers morphological features, the arrangement of cladding elements, architectural integration with other materials, etc.

For each criterion, we defined possible qualitative evaluation ranges (from low to very good; Tab. 2) to select, from the broad range of national and international realisations analysed, the study cases providing as complete an overview as possible of the application opportunities of timber VPWs due to climatic conditions, exposure and technical solutions. As a result of the analysis and evaluation of the case studies concerning the criteria described above, two types of files are systematically compiled (Figg. 6, 7).

The first one illustrates the general characteristics of the intervention and the solutions adopted for the use of exposed wood: a) framework of the work and all the construction, structural and plant engineering aspects and a summary description to highlight the use of wood and/or wood-derived products; b) definition of the VPW functioning scheme (based on the case studies analysed, three functional models emerged: wall insulated from the inside, wall insulated from the outside, and ventilated wall). The second describes the technical solution adopted, according to criteria identified: a) identifying and analysing functional layers and their components, material and performance characteristics required in compliance with the technical regulations in force; b) technical-performance analysis of the elements: based on the information found for each of the functional layers of the VPW, general performance is described with reference to the products used; c) evaluation of the technical-constructive solution according to qualitative criteria (Availability, Recyclability, Integration, Maintainability, Appearance) according to the ranges identified. The analysed solutions were then subjected to a Multi-Criteria Analysis to provide a further, more objective level of evaluation to support the qualitative considerations defined in the first analysis.

The Evaluation of Technical Solutions for Vertical Perimeter Walls: Design Alternatives and Multicriteria Analysis | In the development of the design process and in

CRITERIA	DESCRIPTION	IDENTIFIED QUALITY LEVELS
AVAILABILITY	The issue of availability is linked to both the raw material and the products to be used in construction solutions (industrial processing, distribution, etc.), as well as to the local technical capabilities for processing, installation and maintenance, and the possibilities of recovery at the end of life. The choice of local wood implies the acquisition of local know-how on application possibilities, processing, and treatment of visible components	Low: imported material Sufficient: local material Good: local material with LCA assessment Very good: local material with adequate characteristics in terms of use and durability
RECYCLABILITY	Wood is a completely recyclable material, so the end-of-life of a technical wooden element can present many possibilities for recovery, manifesting itself as a valuable resource in many areas During the design phase, it is essential to define the organisation of the different functional layers according to the external wall functional model adopted, as well as the connection methods between the layers and the surface treatments applied to the outermost layers that guarantee the disassembly/recovery of the individual elements for their possible reuse	Low: non-recyclable material Sufficient: generally recyclable material Good: LCA of product and use of a relevant percentage of recycled Very good: technical elements that can be dismantled and recovered
INTEGRABILITY	Integration between functional layers, referring to the number, quality, and manner of connections Integrability of the external wall with the other technical elements of the building organism (horizontal closures, fixtures, false ceilings, etc.) as well as with the structural and plant-engineering elements, referring to the inspectionability of the plant passages and the ability not to interfere with the load-bearing characteristics of the structural elements Integrability of furniture and/or equipment elements, especially with regard to interior cladding	Low: problematic connections and poor inspectionability Sufficient: good connections but inspectionability not guaranteed Good: widespread integrability (connections, inspectionability, coordination, etc.) Very Good: total integration between elements
MAINTAINABILITY	The maintainability criterion is profoundly linked to Life Cycle Thinking, in that it obliges the designer to foresee the criticalities of the use and management phase of the system, implementing design solutions aimed at minimising the impact of maintenance activities The maintainability criterion of external walls is declined according to the performance efficiency of the elements and is therefore linked to the durability (useful quality: maintenance of quality over time) and reliability (probability that the spontaneous lifetime of a component is actually such) of the designed systems	Low: poor durability of the solution as a whole Sufficient: treatments to improve the durability of the material, but difficult maintainability/replaceabiliy of the element Good: adequate treatments, maintainability of the element Very Good: adequate treatments, serviceability in situ, disassembly
APPEARANCE	The appearance criterion is particularly linked to the cladding layers (external and internal) to be interpreted as the overall quality of the technical solution, together with the material quality of the specific wood species applied Characteristics of the wood species used: the ability to maintain its own characteristics such as colour, consistency, dimensional stability, etc. over time Characteristics of the technical element: the ability to maintain the required performance over time, the quality of the connections between the different elements, the technical solutions for defining the critical points (ground connection, roof connection, connection with fixtures, etc.)	Low: inadequate wood quality for the technical solution Sufficient: good quality of the species and geometr of the technical element Good: quality of details for connections and critical points Very Good: particular relevance of the technical solution

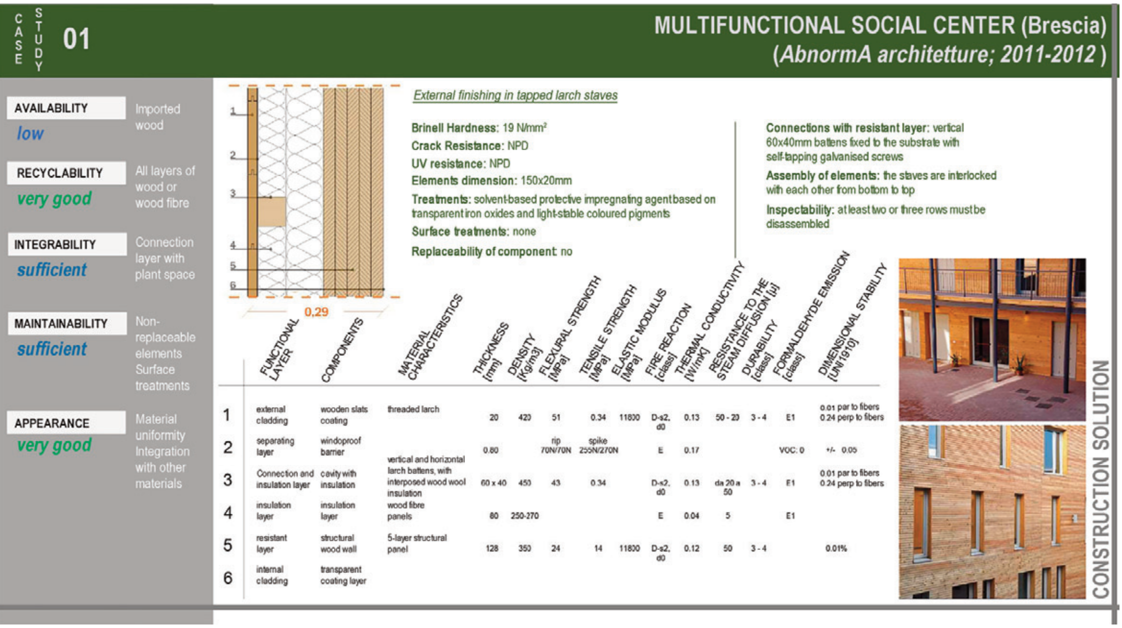
Tab. 2 | Evaluation criteria for external wall solutions (credit: Research Group elaboration, 2020).

an overall vision of the project to ensure its overall quality, the technical and economic feasibility phase is enriched (increasing its operational complexity) by decision-supporting assessments (MIMS, 2021). These assessments can cover different aspects of the project (environmental, technological, economic, managerial, etc.) with the help of specific analytical tools (Fattinnanzzi and Micelli, 2019). Multi-Criteria Analysis (MCA) methodologies are a particularly appropriate and sufficiently rapid tool for structuring the decision-making phase of the designer and have long been used in evaluations of the sustainability and overall effectiveness of architectural works (Ogrodnik, 2019). Their applicability to the assessment of building technologies and especially efficiency in façade design is relatively recent (Moghtadernejad, Chouinard and Mirza, 2018).

In the fourth research phase, we used the Analytic Hierarchy Process (AHP), relying on a range of pairwise comparisons for each hierarchy level (goal; criteria, sub-criteria; alternatives to be tested). Each matrix generated by the pairwise comparison results in scores given by the sum of the comparisons (Al-Saggaf, Nasir and Hegazy, 2020). To assess the overall quality of the design solutions adopted in the case studies for the cladding layers (external and internal) with the use of short-chain wood, we identified the different levels of the hierarchy, the weights attributed over several criteria and sub-criteria were indicated, obtained using a pairwise comparison carried out for each criterion, highlighting for the sub-criteria the importance with respect to the objective and with respect to the reference criterion (Fig. 8).

To increase the effectiveness of the comparison, we defined a balanced number of sub-criteria (max 3 o 4); studies showed that considering less than 3 sub-criteria would lead to an imbalance of the sub-criteria; equally unbalanced would be the distribution of the criterion weight over an excessive number of sub-criteria, leading to them assuming a roughly similar value. Weight assignment took place after numerous analyses of the data from the case studies examined, direct interviews with designers and technicians from the production sector and companies, trying to make even very inhomogeneous data comparable in terms of description and method of measurement, comparing qualitative and quantitative elements. Subsequently, a series of possible pairwise comparisons for each level of the hierarchy came about: 1) the pairwise comparison matrix was drawn up for every criterion, arranging the relative sub-criteria (the sum up of the weights for the sub-criteria of each criteria, must always give 1.00); 2) to the overall target, it arranged the 5 criteria previously described in the qualitative evaluation (the sum up of the weights of the criteria describing the target must always give 1.00).

Considering that the different criteria and sub-criteria are hardly comparable since they are defined by heterogeneous measurement scales (qualitative or quantitative), it required a normalisation process to bring them onto a common scale and to make the necessary comparisons; a-dimensional indexing made it possible to compare the different evaluation elements (Della Spina, 1999). Case studies were analysed using pairwise matrices for each sub-criterion, whose weight is already standardised to that of the reference criterion and the objective. To complete the assessment, a synthesis of judge-



Figg. 6, 7 | Analysis sheets and first evaluation of the case studies (credits: Research Group elaboration, 2019).

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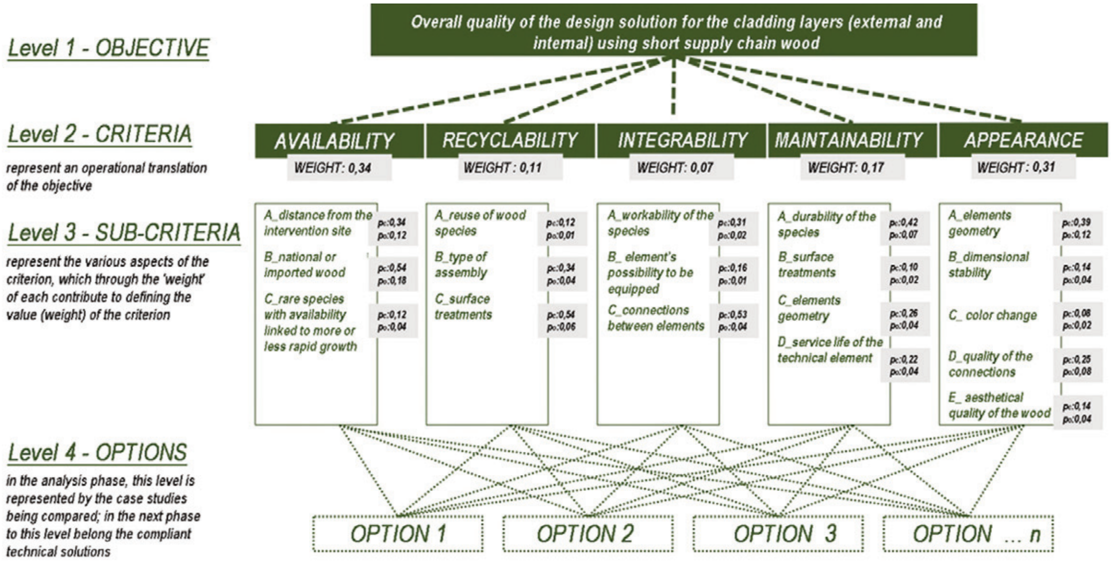
Fig. 8 | Diagram of the hierarchies between the levels of the Multicriteria Analysis adopted (credit: Research Group elaboration, 2020).



ments was carried out, where the scores of each case study were multiplied by the weight assigned to the criteria and based on this synthesis, the case studies themselves were progressively ranked. To better understand the applied methodology, we provide an AHP application to five case studies as an example (Fig. 9), considering those that offer the highest differences in the use of wood for the VPW cladding layers. The examples are described as a whole of the construction solution adopted for the VPW, down to the analysis of the external cladding layers to which AHP is applied (Fig. 10).

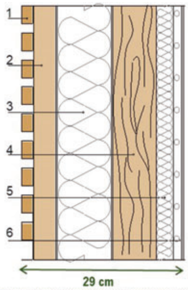
It can be seen from the values shown in the figure how, in general, case study 1 (Woody, Saint Maurice, 2019) is of a higher quality than the others, although it shows low values in recyclability, due to the numerous individual elements (shingles) each fixed with metal connections that make disassembly difficult. While the case study 5 (Multipurpose Social Centre, Brescia, 2011-12) presents in general numerous criticalities in all the evaluation criteria, especially on the criteria of Product Availability (from abroad) and Maintainability, due to the way in which the cladding elements are connected to the support layer (unprotected metal connections). Case Study 4 (Municipal Centre in Estonia, 2010), although presenting a low overall assessment, is characterised by high quality in the Appearance criterion, not only due to the particularity of the morphology of the cladding system used but above all due to the way in which it is manufactured and the special colouring treatment of the elements, which mitigates the effect of time on the colour performance and dimensional stability.

Figure 10, therefore, demonstrates the importance of defining evaluation criteria that investigate the different aspects of the technical-constructive and morphological solution of the VPWs cladding, linked to the choice of raw material and products, the construc-

CASE STUDY 1

WOODY – Saint Maurice (FRANCE) (Atelier DuPont; 2019)

Client: Santé Publique France
Design: Atelier DuPont
Quadriplus Groupe (opere strutturali)
Surface: 4.270 mq
Cost: 10,9 mln di €

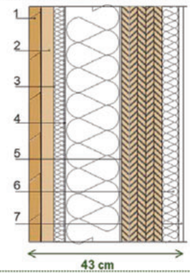


1_External Slavonian oak cladding (2cm)
2_Connection layer with galvanised steel profiles (4cm)
3_Thermal insulation layer made of sandwhich panels (10cm)
4_Wood fibre panel thermal insulation layer (4cm+12cm)
5_X-Lam load-bearing layer (5 layers; 12.8cm)
6_ Internal plasterboard wall with acoustic insulation (5cm+1.25cm)

CASE STUDY 2

KINDERGARTEN (S.Frediano, Settimo) (Colucci & Partners; 2012-2013)

Client: Amministrazione comunale di Cascina
Design: Colucci & Partners;
H.S.Ingegneria s.r.l. (opere strutturali)
Realization: Campigli Legnami (Empoli)
Surface:740 mq
Costi: 1,1 mln di €

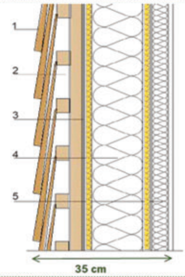


1_ Exterior cladding in larch strips (6cm)
2_ Connecting layer made of untreated larch strips (4cmx4cm)
3_ Wind and UV protection film
4_ Wood fibre thermal insulation layer (4cm+12cm)
5_ X-Lam load-bearing layer (5 layers; 12.8cm)
6/7_ Internal plasterboard wall with acoustic insulation (5cm+1,25cm)

CASE STUDY 3

OFFICE COMPLEX ''TORTONA 37'' (Milano) (Matteo Thun & Partners; 2007)

Client: Pioneer Investment Management SRG
Design: Matteo Thun & Partners;
B.C.V Progetti (opere strutturali)
Realization: Di Vincenzo – Mangiavacchi
Surface: 25.000 mq
Cost: 45 mln di €

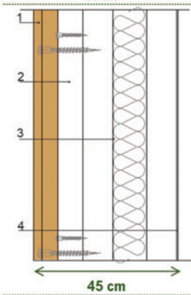


1_Exterior cladding in larch shingles (2cm)
2_Connecting layer made of untreated larch strips (4cmx4cm)
3_Wind and UV protection film
4_Load-bearing layer made of OSB panels and mineral fibre insulation in between (18cm)
5_Internal plasterboard wall with acoustic insulation (5cm+1,25cm), and vapour barrier on OSB board

CASE STUDY 4

MUNICIPAL CENTER IN ESTONIA (Salto Architects; 2004-2010)

Client: Someru Parish
Design: Colucci & Partners
H.S.Ingegneria s.r.l. (opere strutturali)
Surface: 2.400 mq
Cost: 3 mln di €

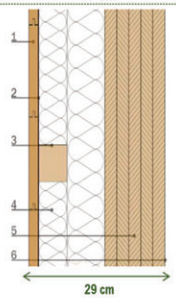


1_Variable-height (5cmx5cm) pine bar covering, attached to the support by means of galvanised steel pins
2_Ventilated cavity (7-9cm)
3_Prefabricated concrete panel (15+15 +12cm) with polystyrene thermal insulation in between
4_Interior finish in enamel paint

CASE STUDY 5

MULTIFUNCTIONAL SOCIAL CENTER (Brescia) (AbnormA architetture; 2011-2012)

Committenza: Immobiliare sociale bresciana
Design: AbnormA architetture
DM Studio (opere strutturali)
Surface: 2700mq
Cost: 3,9 mln di €
Wood elements production: Ka Konstruct



1_External cladding of tapped larch slats (2cm)
2_Separation layer, wind barrier
3_Supporting substructure for the cladding (6cmx4cm)
4_Thermal insulation layer made of wood fibre panels (8cm)
5_X-Lam load-bearing layer (5 layers; 12.8cm)
6_Interior paint finish layer

EVALUATION CRITERIA	SUB-CRITERIA	SUB-CRITERIA WEIGHT		CASE STUDIES									
				normalised values from pairwise comparisons matrices					values compared to the normalised weights of the sub-criteria				
		relative weight on the criterion	total weight on the objective	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5
AVAILABILITY	A_distance from the intervention site	0,34	0,12	0,27	0,23	0,30	0,13	0,08	0,03	0,03	0,03	0,01	0,01
	B_national or imported wood	0,54	0,18	0,38	0,18	0,22	0,15	0,07	0,07	0,03	0,04	0,03	0,01
	C_rare species with availability linked to more or less rapid growth	0,12	0,04	0,32	0,26	0,20	0,15	0,08	0,01	0,01	0,01	0,01	0,00
	WEIGHT Criterion 1		0,34					EVALUATION Criterion 1	0,11	0,07	0,08	0,05	0,03
RECYCLABILITY	A_reuse of wood species	0,12	0,01	0,33	0,31	0,19	0,11	0,07	0,005	0,004	0,003	0,002	0,001
	B_type of assembly	0,34	0,04	0,25	0,34	0,19	0,14	0,08	0,010	0,013	0,008	0,005	0,003
	C_surface treatments	0,54	0,06	0,27	0,34	0,19	0,12	0,08	0,016	0,021	0,012	0,007	0,005
	WEIGHT Criterion 2		0,11					EVALUATION Criterion 2	0,031	0,039	0,022	0,014	0,009
INTEGRABILITY	A_workability of the species	0,31	0,02	0,30	0,22	0,22	0,14	0,13	0,006	0,005	0,005	0,003	0,003
	B_ element's possibility to be equipped	0,16	0,01	0,34	0,26	0,15	0,14	0,11	0,004	0,003	0,002	0,002	0,001
	C_connections between elements	0,53	0,04	0,30	0,26	0,19	0,13	0,13	0,011	0,010	0,007	0,005	0,005
	WEIGHT Criterion 3		0,07					EVALUATION Criterion 3	0,021	0,017	0,013	0,009	0,009
MAINTAINABILITY	A_durability of the species	0,42	0,07	0,29	0,25	0,22	0,17	0,08	0,020	0,017	0,015	0,012	0,006
	B_surface treatments	0,10	0,02	0,33	0,28	0,18	0,12	0,10	0,006	0,005	0,003	0,002	0,002
	C_elements geometry	0,26	0,04	0,34	0,27	0,22	0,08	0,09	0,015	0,012	0,009	0,004	0,004
	D_service life of the technical element	0,22	0,04	0,31	0,29	0,19	0,14	0,08	0,012	0,011	0,007	0,005	0,003
	WEIGHT Criterion 4		0,17					EVALUATION Criterion 4	0,052	0,045	0,035	0,023	0,014
APPEARANCE	A_elements geometry	0,39	0,12	0,33	0,19	0,13	0,30	0,05	0,040	0,022	0,015	0,036	0,006
	B_dimensional stability	0,14	0,04	0,33	0,11	0,19	0,27	0,09	0,015	0,005	0,009	0,012	0,004
	C_ color change	0,08	0,02	0,31	0,16	0,17	0,28	0,08	0,007	0,004	0,004	0,007	0,002
	D_quality of the connections	0,25	0,08	0,36	0,13	0,24	0,21	0,06	0,028	0,010	0,019	0,016	0,005
	E_ aesthetical quality of the wood	0,14	0,04	0,36	0,26	0,19	0,11	0,07	0,016	0,012	0,008	0,005	0,003
	WEIGHT Criterion 5		0,31					EVALUATION Criterion 5	0,106	0,053	0,055	0,076	0,020
								TOTAL EVALUATION	0,32	0,22	0,21	0,17	0,08

Fig. 10 | Summary table of the multi-criteria evaluation developed on the 5 case studies (credit: Research Group elaboration, 2019).

tion method of the cladding system and its behaviour throughout the entire life cycle. Following the application of the AHP for a critical observation/assessment of the case studies, it was possible to identify the performance levels of the different solutions adopted for the wooden claddings based on the criteria of Recoverability, Recyclability, Integrability, Maintainability, and Appearance. The AHP applied to the case studies has highlighted good design and construction practices, correct applications or, in some cases, inadequate performance responses, representing an important reference for an initial structuring of the Repertoire of compliant technical solutions for WPWs with an external and internal facing layer in visible wood, built on Vertical Perimeter Walls whose resistant layer is made of 3 or 5-layer beech X-lam panels (Sciomenta et alii, 2021).

The construction of a Repertory of possible technical solutions of wood Vertical Perimeter Walls | The fifth and last phase of the research concerned the elaboration of possible technical solutions of wood claddings to organise the Repertory, highlighting, precisely through the application of AHP, how the use of certain wood species (or wood-derived products) selected from those most widespread in Italy, can be 'guided' in the design phase through conforming solutions. The repertory is structured in macro-groups of solutions that refer to the most widespread functional models of VPWs; each functional model is then proposed with various alternatives for the cladding layers, intervening in the choice of short-chain wood species, wood-derived products, connection systems between the components, the geometric conformation of the elements, the thickness, etc.

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Fig. 9 | Summary table of the multi-criteria evaluation developed on the 5 case studies (credit: Research Group elaboration, 2019).

PPV_01	_A	_a
Indicates the functional model of the wall	Indicates the arrangement of the cladding elements	Indicates how the cladding is made
Specifically, it is a ventilated external wall with an X-lam structure and (external and internal) wood cladding	Specifically, it is a horizontal element arrangement	Specifically, these are staves/tables placed on top of each other

Tab. 3 | Identification code key of the Repertory card on the external cladding of external walls (credit: Research Group elaboration, 2020).

RVI_A	_a
Indicates the arrangement of the cladding elements	Indicates how the coating is made
Specifically, it is a horizontal element arrangement	Specifically, these are staves/tables placed on top of each other

Tab. 4 | Key to the Repertory card identification code for interior claddings of the external walls (credit: Research Group elaboration, 2020).

The repertory is structured in two parts, dividing the technical solutions for external cladding from those for internal cladding. Solutions combinations for the external cladding with different possible options for the internal cladding can then be evaluated for each specific design ‘context’, also depending on the conditions of use of the various rooms. Each technical solution is described by means of two sheets. To facilitate this, each sheet contains an identification code for the solution (Tabb. 3, 4). The first part of the code describes the functional model of the VPW as a whole, in the three main macro-groups: Exterior insulated wall, Interior insulated wall and Ventilated wall. The second part refers more specifically to the arrangement of the wooden elements: horizontal elements, vertical elements, diagonal elements, and single elements (shingles, small panels, etc.). The third part describes how the different elements are arranged in relation to the support layer (overlapping element system, tongue and groove, juxtaposed elements, etc.).

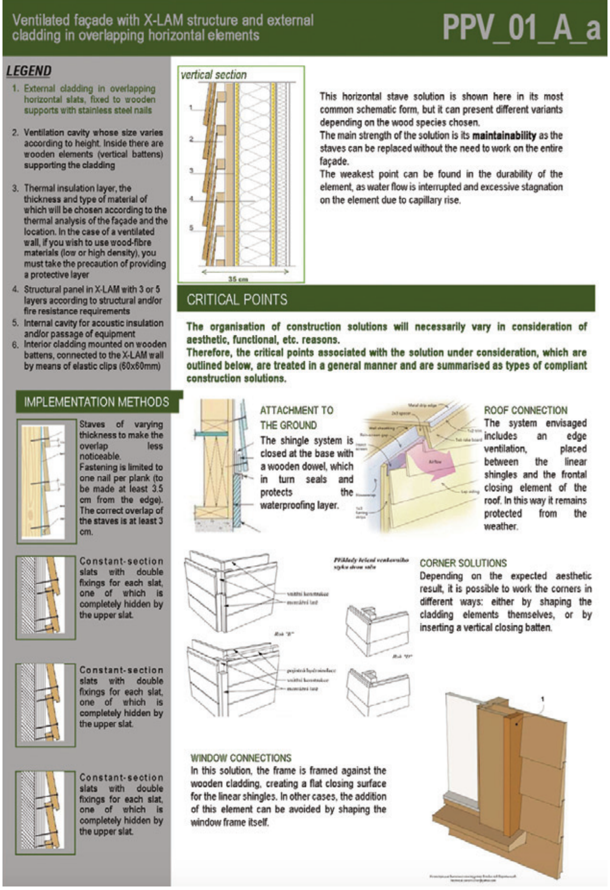
All technical solutions proposed in the Directory feature two sheets: the first illustrates the characteristics of the construction solution of the wooden cladding; the second focuses on the potential/criticality of each material/product that can potentially be used for the specific technical solution, considering short supply chain wood species: larch pine, beech, chestnut and poplar.

Claddings characterised by wood-derived products obtained from the successive processing of veneers, sliced veneers, flakes and particles of short-chain species (WP, C, OSB, KERTO, HPL) were also taken into consideration since for some of the species studied, the use 'au naturel' may entail problems of durability, dimensional stability, etc., while the product derived from the same woods presents better characteristics than the original wood, especially in the case of outdoor exposure. In fact, following discussions with the technical managers of manufacturing companies, it has emerged that there is a considerable diffusion of cladding elements derived from local woods with greater durability; for example, in the case of poplar (a soft, workable, light wood) the market offers products of great interest (plywood, LVL, etc.) suitable for application on walls both indoors and outdoors.

Finally, the sheet shows a summary table with the ratings obtained with the AHP for the various materials/products. As an example, the two descriptive sheets of a Compliant Technical Solution of the Repertory developed for external claddings are shown below (Figg. 11, 12). The AHP, as a support tool for design choices, can be used to make various comparisons: it is possible to compare the applications of various materials/products to a specific technical solution, but it is also possible to compare the different construction methods for the same material/product. The very structure of the Directory highlights strengths and weaknesses for each solution, exposing the different application possibilities of short supply chain woods and leaving the designer, according to his own needs/constraints/objectives, the opportunity to read and use the AHP in the most useful way to provide a concrete aid in the choice of sustainable design alternatives.

The repertory illustrates, for each wood species, the possible methods of use, highlighting, however, greater or lesser applicability of the solutions themselves: for example, in those involving the use of small cladding elements (strips, thin staves, shingles, etc.), the evaluation showed a preference for more workable woods, preferably first-process, as the small dimensions do not allow good yields for wood-derived products. A further point for reflection concerns the variety of surface treatments that can be applied to local woods to improve their ability to resist external agents; in the case of beech, for example, the industry has developed thermo-treatments, treatments based on natural substances and nano-particles to improve its durability (Fioravanti, Goli and Togni, 2019).

Conclusions | As part of the PRIN 2015 research project entitled 'The short supply chain in the biomass-wood sector – Supply, traceability, certification and Carbon sequestration – Innovations for green building and energy efficiency' the structuring of the Repertory represents one of the research products of the group of Technology of Architecture 'Sapienza' University of Rome that has operated within the Operating Unit of the University of Aquila and, as illustrated previously in this paper, not only constitutes a set of technical solutions to guide the design and realisation of claddings for VPWs in visible wood but aims to highlight in a dynamic way how, for each of the solutions presented, the different wood species present in the national territory can be used effectively and sustainably to pursue the technical and morphological quality of the interventions.



Ventilated façade with X-LAM structure and external cladding in overlapping horizontal elements

PPV_01_A_a

LEGEND

1. External cladding in overlapping horizontal slats, fixed to wooden supports with stainless steel nails
2. Ventilation cavity whose size varies according to height. Inside there are wooden elements (vertical battens) supporting the cladding
3. Thermal insulation layer, the thickness and type of material of which will be chosen according to the thermal analysis of the façade and the location. In the case of a ventilated wall, if you wish to use wood-fibre materials (low or high density), you must take the precaution of providing a protective layer
4. Structural panel in X-LAM with 3 or 5 layers according to structural and/or fire resistance requirements
5. Internal cavity for acoustic insulation and/or passage of equipment
6. Interior cladding mounted on wooden battens, connected to the X-LAM wall by means of elastic clips (60x60mm)

vertical section

1
2
3
4
5
35 cm

This horizontal stave solution is shown here in its most common schematic form, but it can present different variants depending on the wood species chosen.
The main strength of the solution is its **maintainability** as the staves can be replaced without the need to work on the entire façade.
The weakest point can be found in the durability of the element, as water flow is interrupted and excessive stagnation on the element due to capillary rise.

CRITICAL POINTS

The organisation of construction solutions will necessarily vary in consideration of aesthetic, functional, etc. reasons.
Therefore, the critical points associated with the solution under consideration, which are outlined below, are treated in a general manner and are summarised as types of compliant construction solutions.

IMPLEMENTATION METHODS

Staves of varying thickness to make the overlap less noticeable.
Fastening is limited to one nail per plank (to be made at least 3.5 cm from the edge).
The correct overlap of the staves is at least 3 cm.

Constant-section slats with double fixings for each slat, one of which is completely hidden by the upper slat.

Constant-section slats with double fixings for each slat, one of which is completely hidden by the upper slat.

Constant-section slats with double fixings for each slat, one of which is completely hidden by the upper slat.

ATTACHMENT TO THE GROUND
The shingle system is closed at the base with a wooden dowel, which in turn seals and protects the waterproofing layer.

ROOF CONNECTION
The system envisaged includes an edge ventilation, placed between the linear shingles and the frontal closing element of the roof. In this way it remains protected from the weather.

CORNER SOLUTIONS
Depending on the expected aesthetic result, it is possible to work the corners in different ways: either by shaping the cladding elements themselves, or by inserting a vertical closing batten.

WINDOW CONNECTIONS
In this solution, the frame is framed against the wooden cladding, creating a flat closing surface for the linear shingles. In other cases, the addition of this element can be avoided by shaping the window frame itself.

Ventilated façade with X-LAM structure and external cladding in overlapping horizontal elements

PPV_01_A_a

MATERIALS

Theoretically, there are numerous application possibilities for timber in horizontal lamella format.
The solutions selected on the side represent those that seem to best meet the characteristics of the building system as a whole

1_Larch Pine

In general, it is the material solution with the best characteristics, because it offers a variety of grains and guarantees good maintainability.
Moreover, its availability is reasonably widespread throughout the country.
The multi-criteria analysis, however, does not take into account the specific aesthetic needs that might prefer woods with other colour renditions, which cannot be obtained with treatments on this type of wood.

2_WPC

It represents an excellent solution especially in terms of durability and maintainability.
Among wood-derived material solutions, WPC is perhaps the one with the widest range of applications.

3_ Poplar

Among the most widespread wood species in the country, it certainly presents difficulties in terms of durability, however, thanks to specific treatments, it has also become very popular in recent years in outdoor applications.

4_ Chestnut

Per la sua colorazione decisa, rappresenta una possibilità applicativa di forte impatto estetico.
Per effetto della sua natura, risulta meno adatto a una lavorazione in elementi sottili, tuttavia, se ben protetti, i singoli elementi possono garantire una notevole durabilità.

5_Kerto

A very interesting wood-derived solution, but one that requires more complex processing cycles.
Moreover, due to its characteristics, it is less suitable for application in thin linear staves.

MULTICRITERIA EVALUATION

The table below illustrates the comparison made between the different material applications.
The evaluations made on the 5 hypothesised solutions, while presenting an objective character of mathematical comparison, leave room for the specific interpretation of the individual application case.

EVALUATION CRITERIA	SUB-CRITERIA	SUB-CRITERIA WEIGHT: relative weight on the criterion	SUB-CRITERIA WEIGHT: total weight on the objective	CASE STUDIES (wood species used) – normalised values from pairwise comparisons matrices: CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	CASE STUDIES (wood species used) – values compared to the normalised weights of the sub-criteria: CASE 1	CASE 2	CASE 3	CASE 4	CASE 5
AVAILABILITY	A_distance from the intervention site	0,34	0,12	0,27	0,23	0,30	0,13	0,08	0,03	0,03	0,03	0,01	0,01
	B_national or imported wood	0,54	0,18	0,38	0,18	0,22	0,15	0,07	0,07	0,03	0,04	0,03	0,01
	C_rare species with availability linked to more or less rapid growth	0,12	0,04	0,32	0,26	0,20	0,15	0,08	0,01	0,01	0,01	0,01	0,00
	WEIGHT Criterion 1		0,34	EVALUATION Criterion 1					0,11	0,07	0,08	0,05	0,03
RECYCLABILITY	A_reuse of wood species	0,12	0,01	0,33	0,31	0,19	0,11	0,07	0,005	0,004	0,003	0,002	0,001
	B_type of assembly	0,34	0,04	0,25	0,34	0,19	0,14	0,08	0,010	0,013	0,008	0,005	0,003
	C_surface treatments	0,54	0,06	0,27	0,34	0,19	0,12	0,08	0,016	0,021	0,012	0,007	0,005
	WEIGHT Criterion 2		0,11	EVALUATION Criterion 2					0,031	0,039	0,022	0,014	0,009
NTEGRABILITY	A_workability of the species	0,31	0,02	0,30	0,22	0,22	0,14	0,13	0,006	0,005	0,005	0,003	0,003
	B_ element's possibility to be equipped	0,16	0,01	0,34	0,26	0,15	0,14	0,11	0,004	0,003	0,002	0,002	0,001
	C_connections between elements	0,53	0,04	0,30	0,26	0,19	0,13	0,13	0,011	0,010	0,007	0,005	0,005
	WEIGHT Criterion 3		0,07	EVALUATION Criterion 3					0,021	0,017	0,013	0,009	0,009
MAINTAINABILITY	A_durability of the species	0,42	0,07	0,29	0,25	0,22	0,17	0,08	0,020	0,017	0,015	0,012	0,006
	B_surface treatments	0,10	0,02	0,33	0,28	0,18	0,12	0,10	0,006	0,005	0,003	0,002	0,002
	C_elements geometry	0,26	0,04	0,34	0,27	0,22	0,08	0,09	0,015	0,012	0,009	0,004	0,004
	D_service life of the technical element	0,22	0,04	0,31	0,29	0,19	0,14	0,08	0,012	0,011	0,007	0,005	0,003
	WEIGHT Criterion 4		0,17	EVALUATION Criterion 4					0,052	0,045	0,035	0,023	0,014
PPEARANCE	A_elements geometry	0,39	0,12	0,33	0,19	0,13	0,30	0,05	0,040	0,022	0,015	0,036	0,006
	B_dimensional stability	0,14	0,04	0,33	0,11	0,19	0,27	0,09	0,015	0,005	0,009	0,012	0,004
	C_ color change	0,08	0,02	0,31	0,16	0,17	0,28	0,08	0,007	0,004	0,004	0,007	0,002
	D_quality of the connections	0,25	0,08	0,36	0,13	0,24	0,21	0,06	0,028	0,010	0,019	0,016	0,005
	E_ aesthetical quality of the wood	0,14	0,04	0,36	0,26	0,19	0,11	0,07	0,016	0,012	0,008	0,005	0,003
	WEIGHT Criterion 5		0,31	EVALUATION Criterion 5					0,106	0,053	0,055	0,076	0,020
				TOTAL EVALUATION					0,32	0,22	0,21	0,17	0,08

EXAMPLES OF REALIZATIONS

1. Denning House (California) – Ennead Architects
2. Casa bifamiliare privata Mut zur Lücke, Innsbruck
3. Active House – LP Arckitektur
4. Complesso residenziale (Vienna) - Schluder architektur / Hagmüller Architects
5. Ville del Parco Adriano (Milano) – Studio A

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Figg. 11, 12 | Sample sheets describing compliant technical solutions for external cladding of the external walls (credits: Research Group elaboration, 2020).

Starting from the assumption that a sustainable approach to architectural design cannot disregard the consideration of the production sector present in the construction context, the theme of the use of wood species from a short supply chain necessarily entails many evaluations regarding the feasibility of construction solutions that expose wood as the outermost layer of the stratigraphy of the VPWs. Therefore, a fundamental step to screen the proposed solutions is represented by the analysis of many case studies, which also highlighted a strong heterogeneity in the design approach, in the morphological, constructive and material solutions, and allowed to develop a tool for the promotion of short supply chain products and for the choice of design alternatives based on assessments as objective as possible (AHP) to be transferred to the definition of the solutions of the Directory.

However, this promotion has to deal with forest resource supply issues (complex spatial articulation, high planning and management costs, environmental risks) that currently severely limit the use of wood in many Italian regions. For this reason, numerous experiments with innovative systems (GIS technologies, remote sensing, etc.) for the inventory, planning and monitoring over time of wood resources on a local scale are underway. Furthermore, the dissemination of short supply chain wood products must take into account the difficulties in certifying the origin of wood and certification, with protocols currently being tested and the desired establishment of a database on the origin and quality of wood at species and geographical area level still being defined.

In future developments, the repertoire could be implemented and managed by means of computer-based systems capable of allowing a faster application of AHP to the proposed technical solutions with different local wood species, using the identified criteria. While in its current configuration the repertoire requires the external cladding layer to be compared and evaluated separately from the internal one, a future implementation with computer-based tools could manage the evaluation of both claddings at the same time. A repertory of innovative technical solutions thus structured to guide the design of sustainable buildings using wood from the local forest heritage, intervening in the containment of supply chains in the construction sector for which it favours ecosystemic conversion and new employment.

Notes

1) For further information refer to the Report Edilizia in Legno (2021) at: federlegnoarredo.it/ContentsFiles/Presentazione%206%C2%B0%20Rapporto%20Edilizia%20in%20Legno.pdf [Accessed 26 July 2022].

2) It should be noted that in our country, for limited local handicraft production, there are production activities linked to native woods; examples are the stone pine works in the Eastern Alps, the cork production and processing industry in Gallura, the use of chestnut in the Apennines, etc.

3) The Italian woodland heritage presents a wide variety of wood species that hint at a concrete

use in the world of construction (both for structural and non-structural use) that is spreading rapidly; an increase in interest in ‘wood architecture’ is, therefore, to be expected, also as a result of a greater awareness of the sustainable use of wood and the resolution of issues such as supply, traceability, sustainability and energy efficiency of the processing chain; careful attention to the production process of wood-based technical elements, also as a result of an increasingly precise regulatory framework; widespread technical knowledge about the material, its performance characteristics (technological and expressive) and the criticalities to be compensated for; research into treatments to improve its durability.

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TREE-FAÇADES
Integrating trees in the building envelope as a new form of Façade Greening

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ABSTRACT
This research aims to look at the possibility of making trees a part of the building, especially façades, to improve the thermal comfort in and around the building. Furthermore, integrating trees in building envelopes could generate new aesthetic and spatial possibilities for the design. By building on the methods of research by designing and research through drawing, tree façades are investigated in different scenarios concerning the building-tree interaction. The outcome of the study is that tree façades could become a new approach for designers of a so far unexplored, aesthetical, and microclimatic aspect of architecture. When implemented in an urban planning scale, tree façades could create networks of habitats that are otherwise typically fractured in the urban fabric. The idea of tree façades is somewhat new and revolutionary not only for future architecture in Germany but for other countries in the world. This basic research could open more doors in architecture and infrastructure. It could contribute to reformulating the way we merge our built environment with natural systems.

KEYWORDS
tree façade, building greening, living architecture, sustainable design, urban heat island

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Architects and landscape architects are confronted with numerous challenges in developing spaces for humanity and biodiversity in the current global warming and climate change crises. The concern of the research project at hand is to address strategies for mitigating rising temperatures in the urban fabric. Nearly half of the world's population lives in cities (Ritchie et alii, 2018), and cities account for three-quarters of the European population (Eurostat, 2016). It takes an increased amount of energy to cool buildings in urban areas during heat waves compared to average summer weather. The fundamental issue is that rising temperatures are having a deplorable influence on the well-being of the residents. Due to the heat island effect urban areas are more likely to get affected causing distress in the lifestyle (Gamble et alii 2013, 2008). With rising summer temperatures in cities, conventional cooling systems demand a significant amount of energy to keep buildings cool (IEA, 2018). Therefore, developing nature-based, low cost and low-energy cooling techniques is vital. Nature-based Solutions are defined by Cohen-Shacham et alii (2016, p. 5) as «[…] actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits». By such solutions, our cities and urban landscapes might be transformed into 'urban ecosystems' at the forefront of climate change mitigation through rethinking urban design, architecture, transportation, and planning (EEA, 2010). Sustainable low-energy housing designs are an integral part of developing communities in ways that encourage lower per capita energy use.

Against this background, building façade designs need substantial reconsideration. Vertical gardens are one such possibility (Hoelscher et alii, 2016; Besir and Cuce, 2018; Perini and Pérez, 2021), but they require a lot of mechanical and engineering equipment to operate (Perini and Rosaco, 2013). On the other hand, ground-based vegetation such as trees, are inexpensive, sustainable possibilities that can reap substantial benefits (Morakinyo et alii, 2017; Rahman et alii, 2019; Franceschi et alii, 2022). To further explore the possibilities of the latter option a group of architects, landscape architects, and engineers have collaborated to develop and investigate a basic concept named tree façades. The research project on tree façades as a climatically effective, innovative form of building greening – funded by the German Environmental Foundation DBU – aims at incorporating trees into buildings, especially façades, to improve the thermal comfort in and around the building and to investigate the aesthetic and spatial possibilities that come with the integration of trees into building envelopes.

Due to their large leaf mass and the spatial depth of the canopy, trees growing close to façades could provide microclimatic effects that go far beyond the usual two-dimensional façade greening techniques: local temperature reductions of up to 3.5 °C using trees versus 1.3 °C using façade greening (Pfoser et alii, 2013) and temperature decreases of 9 °C on the façade (Berry, Livesley and Aye, 2013) are possible. Various studies have shown that a tree near a building can offer a variety of comforting microclimate advantages. Most European temperate climates including Germany contain predomi-

Fig. 1 | Half-crown tree at TUM Campus Munich (credit: F. Ludwig).

Fig. 2 | Half-crown tree at Jägerstr. 2-6 Munich (credit: Mahtab Baghaiepoor).

nantly deciduous trees. In the summer they provide shade and let the light through during the winter when all the leaves have fallen. A medium-sized deciduous tree with leaves will reduce irradiance by 80% and one without leaves by 40% (Heisler, 1986). Trees can cool the building surfaces or façades and thereby lessen the energy load for cooling (Akbari, 2002; Pitha et alii, 2018). The heat exchange between buildings and their surroundings is lowered when tree shade reduces the glare of light diffused from the sky. This has a significant impact on people's comfort, reducing heat stress (Abdel-Aziz, Al Shboul and Al-Kurdi, 2105). Trees contribute significantly to the radiative exchange process of ground and wall with considerable reductions in surface and air temperatures. As a result, tree shading is critical in lowering the ambient and surface temperatures of any artificial surface in urban built-up areas, which will indirectly reduce building energy usage (Akbari, 2002; Abdel-Aziz, Al Shboul and Al-Kurdi, 2015).

Apart from the microclimatic benefits of integrating trees into the building façades, trees generate interesting atmospheres within a spatial layer surrounding the building itself. One can imagine living among the trees experiencing the crown with branches and leaves, trunk and bark along with seasonal changes of the whole organism. Aesthetically, trees break the regularity of the building façade and could be separators, avenues at balcony level, privacy providers and many more. Tree façades create a new dimension for designers to explore and generate various temporal atmospheres and even ecosystems in the building envelope (Canepa et alii, 2022). The present research project aims to develop construction principles for the integration of trees in façades and to explore the spatial design possibilities in typological studies. This is done in the context of a concrete case study in Bamberg, Germany. Before the methods 'research by design' and 'research through drawing' as well as the results are presented, the following will explain the approach, define it and distinguish it from other forms of green façades.

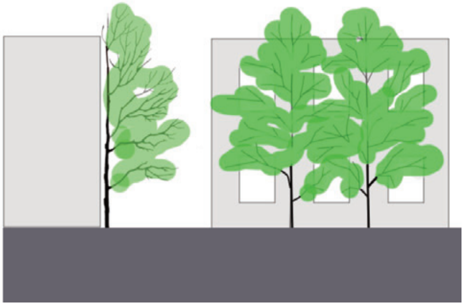
Definition of tree façade | In actual city planning trees are normally planted at a certain distance to buildings to give the tree enough space to develop both crown and roots but also to protect the building façade in case of storm events. Concerns regarding damages to the building foundation or underground infrastructure through roots are also common (Overbeke, 2008; Fernandes et alii, 2019). As a result, seeing or planning trees and buildings closely together is uncommon. However, a substantial amount of very tight growing, mostly private but also some public trees can be observed in the urban context, as shown in Figures 1 and 2 for examples in Munich.

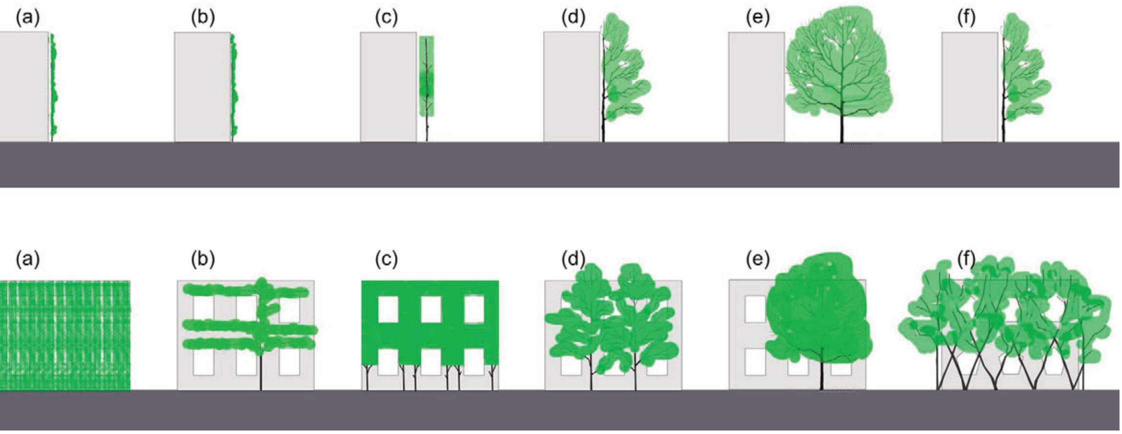
If a tree is growing directly in front of the façade, its normal reaction is to minimize branch and crown development towards the façade and maximize it towards space and light. By intentionally planting trees close to a building and speeding up the natural growth pattern by pruning, it leads to the following definition of a tree façade: A tree façade consists of expansive, large-crowned trees that are planted so close to a building that the tree crown visually becomes part of the building from the outside, while the user of the building can experience the crown space directly from the inside

Fig. 3 | Schematic section (left) and front view (right) of a tree façade (credit: L. Höpfl).

Fig. 4 | Section and elevation of (a) ground-based façade greening with climbers, (b) espalier tree, (c) hedge façade, (d) tree façade (e) tree in front of a building, (f) façade of inosculated trees (credit: L. Höpfl).

Fig. 5 | Hedge façade at Gites Ruraux des Jupilles (credit: C. Guillaume, Gites les Tropes).





or the balcony. Planting the tree close to the façade, accompanied by maintenance pruning measures, leads to the formation of a 'half-crown' (Fig. 3).

To illustrate the difference between a tree façade following this definition and other ground-based façade greening systems the various approaches are compared in Figure 4 in section and elevation. The first category (a) consists of climbers growing on support structures (e.g. trellises, wire ropes) that are mounted at a certain distance from the façade. Depending on the arrangement of the support structures and the selected species this kind of façade greening can have various climatic effects on the building mostly through shading (Pfoser et alii, 2013). Espalier trees (b) are trees that are attached to a trellis structure and shaped into the desired growth form by means of pruning and bending the branches. The canopy has a shallow depth, comparable to the climbers of the category (a). The espalier form aims to use the heat storage capacity mainly of south-facing walls to increase the yield of the fruit tree varieties that are frequently used. A cooling effect is not to be expected very high with the espalier tree, due to the mostly low coverage of the façade. A hedge façade (c) planted directly in front of the façade consists of several trees at close distance to each other, whose canopies are kept in a certain, often architecturally predetermined shape by means of pruning. In this way, windows can be deliberately kept clear to allow the user an unrestricted view of the outside. In contrast to the espalier tree, the hedge façade has a spatial depth of at least one meter. Depending on the canopy volume, hedge façades can have a climatic effect on the building.

On the other hand, a possible limitation of a hedge façade is a relatively high demand for pruning and maintenance efforts, to keep it in the desired form, and a limitation of vertical expansion due to a limited number of high-growing suitable hedge species. A well-known example is the hedge façade of the project Gites Ruraux des Jupilles, designed by the Architect Edouard Francois (Fig. 5). The tree façade (d) systematically stands between (c) and a freely growing tree in front of a building (e), with a large enough distance to the building for the crown to develop fully. For freely growing trees, pruning measures are usually not planned, unless it is a topiary tree or as a safety measure in old age. Although such free-standing trees growing in front of a building develop a large crown volume, the potential climatic effect is limited to parts of the façade only. As a result, cooling effects through shading and transpiration are only possible to a limited extent.

In a direct comparison of all mentioned building greening solutions (Tab. 1), on the one hand, the high design and climatic potentials of tree façades become clear, on the other hand, the complexity of tree façades regarding planning and maintenance is obvious. To exploit the potential and find adequate answers for the challenges is the motivation of the research project at hand.

Methodology | The starting point of this research about tree façades was a request for a tree-integrating architecture in a currently planned social housing project in Bam-

	Planning complexity	Possible variability in design	Potential climatic effects	Effort & Maintenance
Climbing plants (a)	medium - high	medium	medium	medium
Espalier tree (b)	medium	low	low	high
Hedge façade (c)	high	high	high	(very) high
Tree façade (d)	medium - high	high	(very) high	(medium) high
Tree in front of a building (e)	low	low	medium	low

Tab. 1 | First comparison of ground-based building greening solutions to illustrate the potential benefits and challenges of tree façades (credit: L. Höpfl and F. Ludwig).

berg, Germany (Hereinafter referred to as the Bamberg project). A multidisciplinary team of architects, landscape architects and civil engineers came together and found an already well-advanced planning stage of building and site development. Within the framework of the Bamberg project's specifications, possibilities for tree façades were elaborated. Problem identification, common language finding and various design approaches are achieved using drawing as well as graphical analysis (Well and Ludwig, 2020) as tools. In this well-established method called Research by Drawing the building-tree interfaces are understood by drawing, discussing, revising, and comparing, to drive the development process. Various scenarios can be designed and refined in response to the suggestions and knowledge of the interdisciplinary research participants (Bobbink and Loen, 2020; Mäkelä, Nimkulrat and Heikkinen, 2014).

In the case of Bamberg, elements of the Research by Design were applied using «[…] designs to research spatial solutions for a certain area, accommodating a design process, consisting of a pre-design phase, a design phase and a post-design phase, herewith providing a philosophical and normative basis for the design process, allowing to investigate the qualities and problems of location and test its (spatial) potentials, meanwhile creating the freedom to move with the proposals in uncharted territory, and producing new insights and knowledge interesting and useful for a wide audience» (Roggema, 2017, p. 15; Well and Ludwig, 2021).

After coming to specific insights and solutions for the Bamberg project, structural and typological aspects were elaborated using abstraction to transfer into other architectural settings. A deep literature review, especially regarding site conditions at façades, possible tree species, maintenance practices, and also tree moving and static aspects in windy and stormy conditions, was conducted, starting with the Bamberg project and then transferring it to general guidelines. In addition, finite element simulations using geometric nonlinear analysis were carried out to investigate the movement of trees in the wind and any critical stresses that may occur at joints. Since a detailed presentation of this method and the results would go beyond the scope of this article, which focuses on the qualitative aspects of the research, the results section only briefly discusses the most important findings to be able to assess the developed variants in this regard.

Results | Based on the Bamberg Project, basic reflections, critical factors and conceptual considerations arose. It turned out, that understanding tree behaviour and tree static is a key factor in designing tree façades. For Bamberg, three variants (Variant 1-3) were developed from a structural point of view and abstracted for transferring into other contexts (see structural variant results). Another important outcome is a new understanding of the spatial effect of living in the tree crown and the possible atmospheric experiences of a growing and seasonal changing organism. This was particularly developed within the second variant, which uses access balconies for temporary support of the tree façade and is therefore called Laubengang-Typology[1]. As a third result, an approach to aesthetical qualities shows the potential of using tree façades as a way to tie nature experience and human wellbeing together, not only by improving microclimatic effects provided by the tree but also by generating multiple sensual stimuli (see aesthetical results).

Elaborated structural solutions | The three variants presented in this section are motivated by the distinct consideration of the tree in its development from a young tree to a mature tree, as well as its respective wind behaviour. Different flexibility or stiffness gradients exist in the trunk and branches depending on the stage (Fig. 6), resulting in varying degrees of movement behaviour based on wind strength. As a result, the tree and building are vulnerable to harm at various periods and points: 1) Due to insufficiently attached roots (at planting or due to poor root development), the tree may tip over from or towards the building, leading to removal; 2) Shoots, branches, and twigs can strike the façade and break off.

From here, two ways to establish a tree façade were defined: either secure and support the tree temporarily/permanently or integrate the tree's movement into the building design. Also, the process of growing needs to be integrated into the architecture, which leads to interesting changes throughout the development. For the Bamberg project, the following three exemplary variants were developed, typical situations were taken up and possible interfaces were considered and are shown in an overview in Figure 7:

– Variant 1 is a scaffold pole that is permanently but elastically fixed to the building; the leading shoot of the tree is fixed to the scaffold pole during planting and continu-

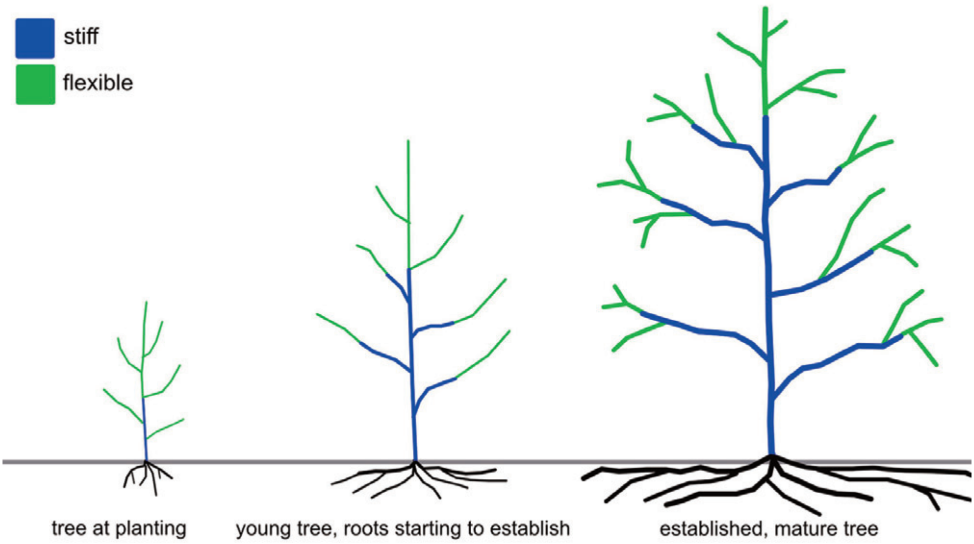


Fig. 6 | Schematic representation of the tree flexibility-stiffness in 3 age stages (credit: L. Höpfl).

ously pulled around the pole as it grows; the aim is to achieve a permanent intergrowth of the pole and the tree;
– Variant 2 uses structural elements such as loggias, balconies or arcades to integrate a structural element that embraces the tree and fixes it temporarily and only in tension (e.g. with ropes) until sufficient rigidity of the tree is achieved;
– Variant 3 leaves the tree with a little more distance in front of the building so that the tree can move relatively freely in the wind; here, temporary support systems are only envisaged during the establishment phase.

Variant 1 | This variant places the trees of the tree façade at a very small distance (less than one meter) from the building. However, the tree should not be placed closer than half its root ball size when planted, so that the tree is not weakened by additional highly intrusive pruning measures in the root area. The proximity to the building means that the root space to one side is severely restricted and the roots can only spread away from the building. To assist the young tree in its anchoring and growing process and to protect the older, more stable tree with a flexible shoot tip from buckling in high winds, a pole is proposed to reduce leverage, prevent the tree from tipping over, and stabilize the tip (Fig. 8). In this variant, the scaffold pole is designed to be permanent. The elastic shoot tip is regularly wrapped around the scaffold pole so that the tree and the pole grow into a single unit over time as the tree grows in thickness (Figure 9; compare the research on Baubotanik structures[2]; Ludwig and Storz, 2005; Ludwig, 2008, 2021; Ludwig, Schönle, and Vees, 2016).

As the tree grows in height, an expansion of the circumference is essential to ensure the tree's supply and stability. Division processes in the cambium, the tissue layer under the bark, lead to a ring-shaped enlargement of the shoot. If there is an obstacle in the zone of thickness growth, such as the scaffold pole, in this case, it is enclosed and inosculated over time in such a way that the pole is only partially visible from the outside, or not at all. The shoot-scaffold pole connection is elastically supported via a tension-compression spring at special connection points on the building, whereby the coupling of the static system building, and the flexible system scaffold pole-tree is a challenge that should be considered early in the planning process (Fig. 10). Detailed finite element modelling of the inosculated pole and its direct connections to the building showed that there is a risk of stress peaks at the end when the tree outgrows the pole as well as at the support points. This can be avoided by a gradual load transfer from the tree into the support, either by elastic connection details between the pole and building or a gradual decrease in stiffness of the pole towards the crown of the tree.

Maintenance of variant 1 includes regular pruning of branches that may grow towards the façade as well as continuous guidance of the shoot tip around the scaffold pole. Due to the small distance from the façade and overhanging branches of the tree, the accessibility of the trunk is limited. If the building has a parapet, specially trained gardeners or tree climbers could rappel down from there and operate directly between the building and the tree façade. This would allow for very precise maintenance. Alternatively, maintenance can be carried out from the ground using ladders or a lifting platform, whereby the accessibility of the ground must be guaranteed without harming the root space of the tree façade. In Variant 1, the building and the tree merge almost completely through the physical connection and spatial proximity. This creates not only a constructive but also a visual unit, which leads to new spatial qualities in and around the building.

Variant 2 | This variant integrates the tree into an existing component of the building like a loggia, a balcony or an arcade and fixes it temporarily. This places the tree at a defined distance in front of the building, which on the one hand restricts the root space less and on the other reduces the risk of damage to the tree or the façade in windy conditions. Depending on the stage of development (Fig. 11), the tree is tied temporarily in suspension to special devices integrated into the building component, for example using elastic tree ties or coconut ropes. The fixtures can be recessed or cantilevered railings or guides (Fig. 12). Once the tree is established, the temporary ties are removed.

Finite element modelling has shown that stress peaks can occur in the trunk during strong gusts if it is directly connected to a fixed support. The additional stiff support leads to the highest bending moments at the upper part of the trunk rather than at the root. This can lead to the so-called 'karate effect' where the trunk breaks above the support in the case of high dynamic wind loads (Detter, 2019). To prevent the tree from breaking, the trunk should instead be held elastically, e.g. with ropes and elas-

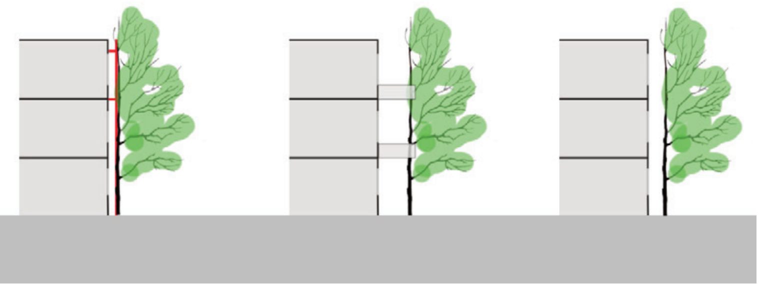


Fig. 7 | Connection with the ingrowing pole – Variant 1; Temporary connection – Variant 2; Tree standing freely in front of façade – Variant 3 (credit: L. Höpfl).

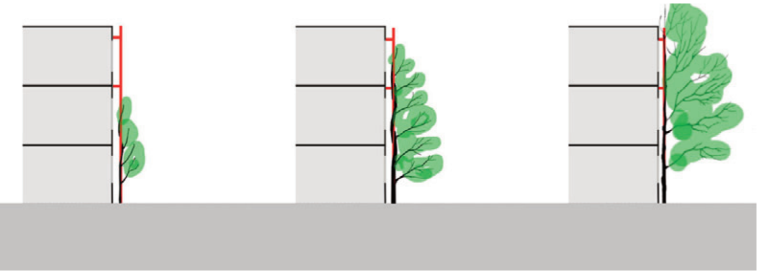


Fig. 8 | Development over time of Variant 1 (credit: L. Höpfl).

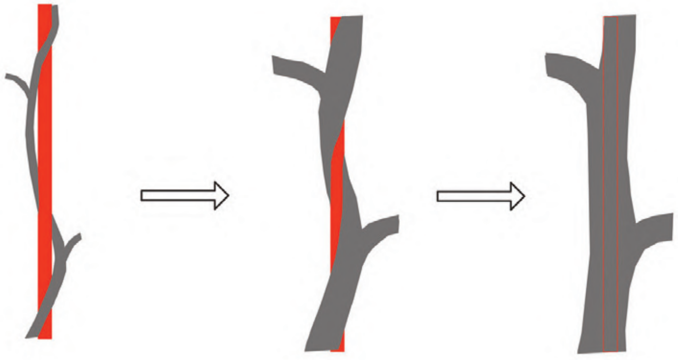


Fig. 9 | Inosculation process of the shoot tip and the pole (credit: L. Höpfl).

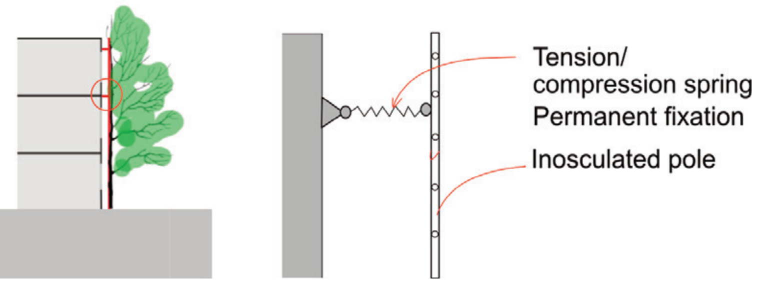


Fig. 10 | Schematic structural detail of Variant 1 (credit: L. Höpfl and J. Lienhard).

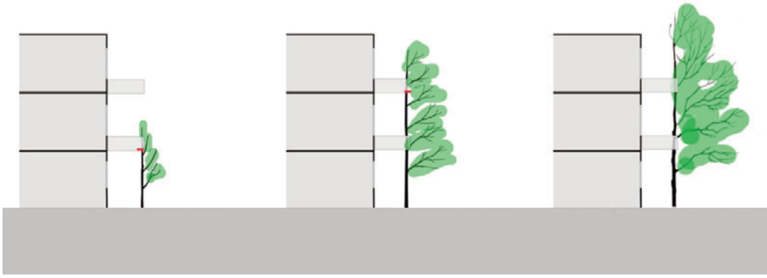


Fig. 11 | Development over time of Variant 2 (credit: L. Höpfl).

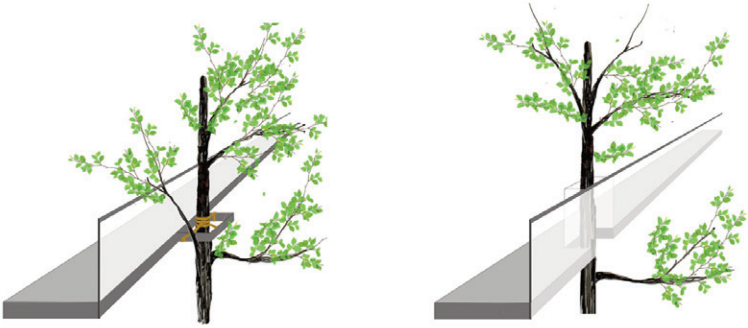


Fig. 12 | Possible tree and building joinery (credit: L. Höpfl).

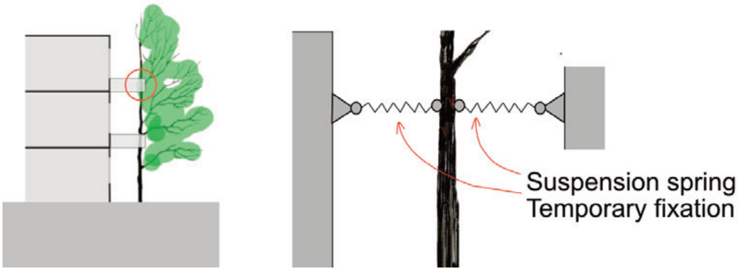


Fig. 13 | Static of Variant 2 (credit: credit: L. Höpfl and J. Lienhard).

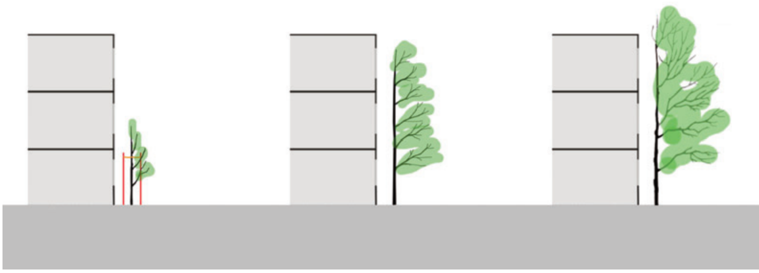


Fig. 14 | Development over time of Variant 3 (credit: L. Höpfl).

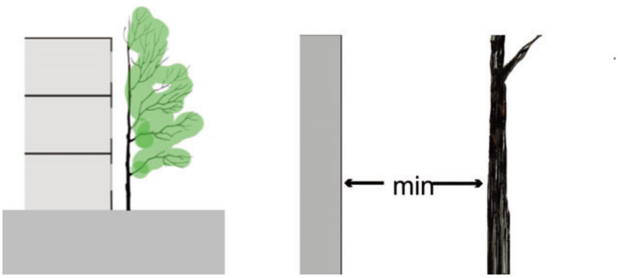


Fig. 15 | Static detail of Variant 3 (credit: L. Höpfl and J. Lienhard).

Comparison	Way of fixing	Complexity of planning	Maintenance	Effort & cost	Possible distance to façades
Var 1 **Permanent fixing with inosculated pole**	permanent, elastic, Tension-compression anchoring	high	demanding	high	Very low
Var 2 **Temporary fixing**	temporary, Tension- anchoring	medium	medium	medium	Depending on the building structure
Var 3 **Tree with distance to the building**	temporary while establishment phase (planting)	medium	medium	medium	low

Tab. 2 | Comparison of structural variants (credit: L. Höpfl and F. Ludwig).

tomeric dampers (Fig. 13). The maintenance of this variant is limited to the pruning of branches growing towards the façade and the control, adjustment and removal of temporary tethers. If balconies or pergolas are provided on the building anyway, this is a simple and relatively inexpensive way to establish the tree façade. Spatially, this variant can appear more distant, depending on the size and design of the architectural component the tree is integrated into. However, skilful planting at corner positions can create a tree façade privacy screen, which in turn has a spatially and climatically interesting effect (see special application results).

Variant 3 | This variant moves the tree away from the façade at a greater distance (more than one meter) and ties it independently of the building and only temporarily, for example, with a tree stake, tripod or underfloor system after planting until the roots are sufficiently anchored in the ground to stabilize the tree (Fig. 14). The distance kept from the façade allows the roots – at least partly – to develop in both directions, which has a positive effect on the development of the entire tree. The swinging of the branches in the wind and a possible touching of the façade is accepted here.

By using the finite element model, deformations of a free-standing half-crown tree under strong winds can be determined. The simulated trunk and branch movements provide information about the necessary distance of the tree from the façade so that both the façade and the tree are not damaged in a storm (Fig. 15). The results vary depending on the chosen species and the age of the tree. The maintenance of Variant 3 consists only of the removal of the temporary fixation in the ground after the establishment of the tree façade and regular pruning of the branches growing towards the façade. Accessibility depends on local conditions. Variant 3 has no direct interfaces with the building and is, therefore, more cost-effective in terms of establishment and maintenance, but here possible movements of the tree towards the façade must be planned for in the event of strong winds. Depending on the building type and available resources, the structural variants of the tree façade presented here are differently suitable for integration into the architectural concept: Table 2 shows a comparison.

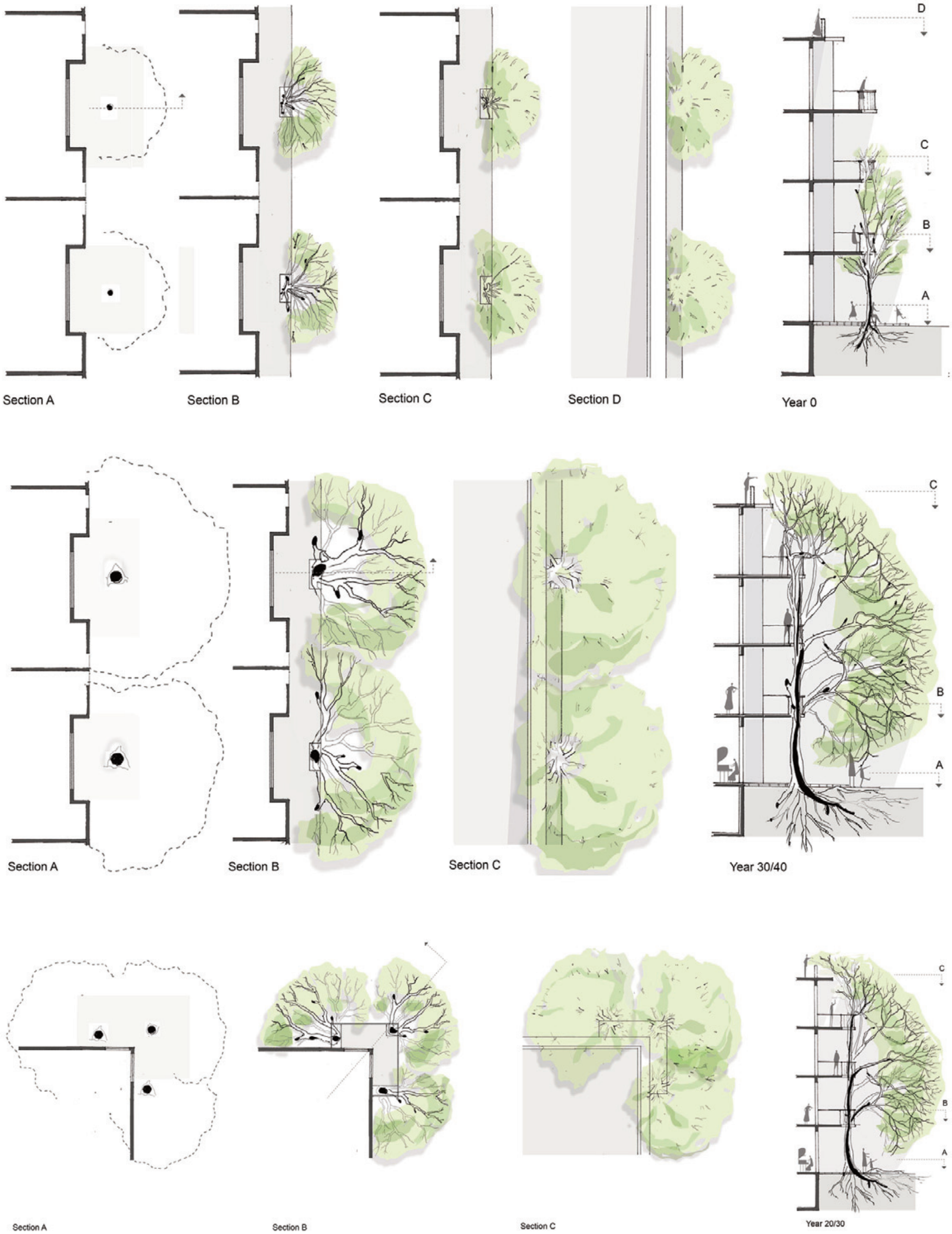
Elaborated spatial typologies | Applications of tree façades and their spatial features were explored by elaborating three typologies of the structural Variant 2 described above by placing trees in front of, around, and between balconies or corridors, considering the following aspects: 1) Time – while the overall shape and appearance of the building is completed when first users move in, the tree façade is still in the early stages of growth at the time of planting; the process of developing an effective height and crown volume takes 20-40 years; spatial experiences are therefore under constant change; thinking in such time dimensions influences also the life cycles and needs of the inhabitants as well as the social components of the architecture; 2) Light – figuring out the balance between enough light for and views out of the spaces over the summer while reducing temperatures in the exterior and interior spaces; design factors here include the distance of the trees from the building, the tree species with its canopy structure and foliage density, and the density of the tree façade planting itself.

Laubengang typology – Cantilevered corridors allow the trees to be fixed, at the same time it serves as a platform for maintenance. While the shading of the façade is ensured by the cantilevered corridors even at the beginning of planting, the previously open corridor itself is increasingly screened by the trunks and branches of the trees in the further growth process (Figg. 16-18). The façade also changes from the outside perspective with the growth of the trees and the foliage in summer.

Green Niche typology – A tree façade planted around a corner balcony allows life inside the trees like in a green, sheltered cocoon. Temporarily attached to the balcony, the trees develop an internal space on the balcony and enhance an introverted feeling (Fig. 19).

Screen typology – Trees between the balconies allow a natural separation between nearby balconies and life in the tree while the balcony allows an open view of the surrounding. Depending on the distance, the crown close to the balcony can be experienced from the inside whereas the neighbouring crown will be experienced from the outside.

Elaborated spatial and aesthetic results | The spatial component and the effect of the tree façade depends on the distance and arrangement of the trees in front of the building, but equally on the age of the trees and the height from which the tree crown is experienced. The experience of living in a tree changes in the course of growth, but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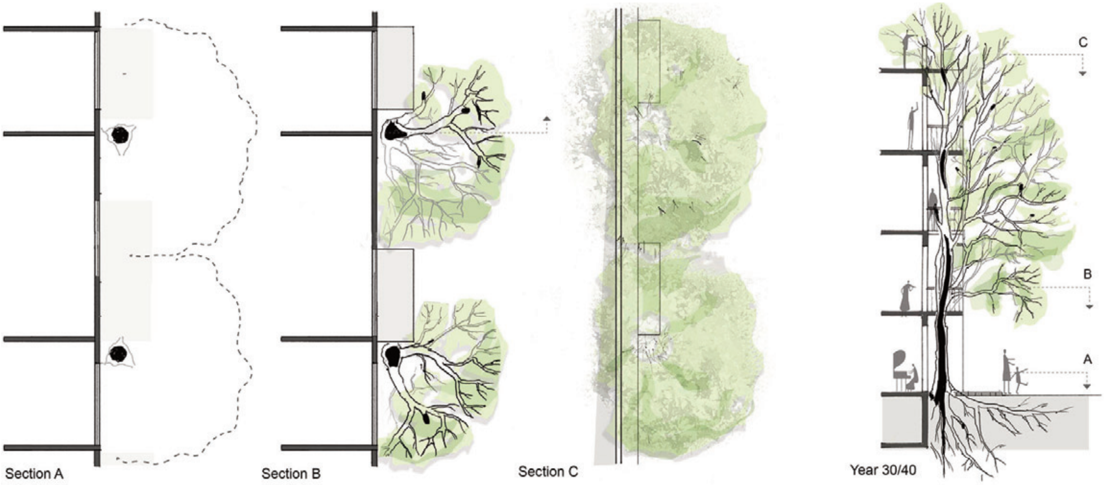

Fig. 19 | Mature trees acting as a separator between the balconies, approx. 20-30 years (credit: D. Pilla and F. Köhl).

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Fig. 16 | Trees in front of the house: Laubengang typology at the time of planting (credit: D. Pilla and F. Köhl).

Fig. 17 | Mature trees in front of the corridor: Laubengang typology (credit: D. Pilla and F. Köhl).

Fig. 18 | Mature trees on the corner balcony, approx. 20-30 years (credit: D. Pilla and F. Florian Köhl).

also within the seasons: while the freshly planted tree can initially only be experienced in the lower storeys, the crown as a whole is still small and the spatial depth rather shallow, over the years it develops into a large, shady tree that creates its own crown space on each storey through the depth of its branches. Depending on the season, the trunks, branch structures and foliage create a carpet of plays of light and shade on the façade, balconies or arcades, extending into the living spaces. The views also change with the season, the age of the tree and the experienced height of the treetop: in winter, light enters the living spaces, and the view opens, guided by branches into the surroundings, while in summer the foliage allows more partial views and inspires an introverted experience of the closer treetop.

The immediacy of the tree allows the user to experience its characteristics visually, but also haptically: the texture of trunk, bark and branches, the settling of mosses, the hibernation of buds in the cold season, only to sprout in spring and be blown away as colourful leaves in the autumn wind. Rain and wind also play a key role in the experience of spatial-sensory qualities. Through the slight or strong movement of branches and leaves, the delayed dripping of water after a summer rain or the snow on the branches in winter, weather and season suddenly become immediately visible and are enriched by new, not everyday observations, such as sounds of flapping branches and

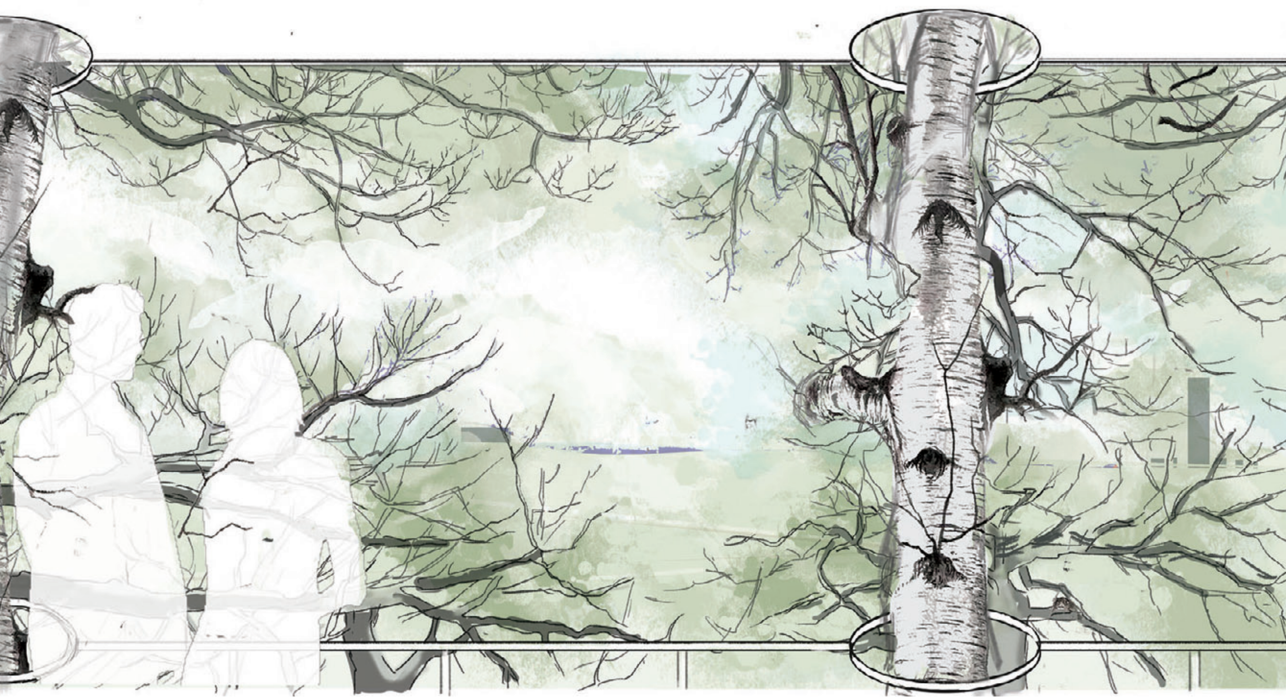

Fig. 22 | Tree façade framing the view (credit: D. Pilla and F. Köhl).

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Fig. 20 | Tree façade perceived from interiors (credit: D. Pilla and F. Köhl).

Fig. 21 | Tree as a substantial element of the balcony (credit: D. Pilla and F. Köhl).

rustling leaves and smells of fresh leafy greens, bark or rain. This and the possibility to observe birds and insects on the balcony or from the living room brings a new kind of experience of nature into the user's immediate living environment. These qualities have been elaborated by a series of perspective drawings (Figg. 20-22).

Discussion and Conclusion | A tree façade is a project dealing with various interfaces. From the Bamberg project and the resulting design research, the following conclusions can be drawn for a tree façade approach. First, there is a necessity in overcoming obstacles in the multidisciplinary cooperation with Architects, Landscape Architects, Structural Engineers, Gardeners, and stakeholders involved in the planning process. Therefore it is important to understand the different approaches and tasks of each discipline, to develop a new, integrated language, and implement new methods for decision making. It turned out that by using drawing and designing as a method, content and conflicts can be identified very quickly. Besides, it was shown that for integrating time and process in the planning practice drawing is a comparative tool which is easy to understand and to use for all involved actors. Still, it remains a challenging task for all planners to fully imagine various spatial and atmospheric experiences, especially considering constant change, as most disciplines are trained to think in non-changing results. Also, cross-disciplinary consequences of using tree façades, like an adaption of floorplans or different designs of foundations for buildings, bear enormous potential that is not revealed yet in the building practice, and trees are often treated like an 'add-on'. Coming together in an early planning stage is therefore crucial (Well and Ludwig, 2021).

The results of the paper are limited to the insight gained and abstracted from the Bamberg project. As theoretical research, it now needs practical implementation and monitoring both in the Bamberg case and elsewhere. Assembly of data and regular documentation over time must demonstrate the microclimatic and other beneficial effects of building with trees. As Bamberg is a social housing project the impact on the residents and the influence on the social interaction should be stated and investigated over time. Also, it is very likely that a natural feeling of distance and the positive effect of looking into green leaves reduces stress (Huang et alii, 2020) and improves social performance (Kuo and Sullivan, 2001).

In dense urban areas tree façades present a completely new way of merging building greenery and urban green, stacking benefits of cooling and shading, and other ecosystem services, but also hold the option to develop a whole new streetscape. This allows for example to reorganize pedestrian, cycle and motorized zones, having trees close to buildings and more open space towards the middle of the street. As tree facades hold potential for various benefits beyond the building (e.g. shading and cooling the street), the cost for investing and maintenance remains with the developer or owner. This is also an issue for future discussions and invites to develop progressive and interwoven responsibilities between the municipality and stakeholders.

The study at hand can be seen as the first attempt in those directions. If proven, tree façades could serve as a model for future architects, planners, and engineers in a multidisciplinary forum for designing solutions for adaptation to climate change on the urban scale, but also to elaborate high-quality building environments with nature integrated into the architecture. The study, however, was limited to Northern Europe, specifically Germany. This may limit the design's applicability in other regions of the world but does not rule out the possibility of tree façades in other climates.

Acknowledgements

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Notes

1) Laubengang Typology in this case means arcades build from trees or in terms of horticulture: an arbour walk.

2) The term Baubotanik describes a form of architecture in which structures are created through

the interaction of technical joining and plant growth by manipulating the growth of trees or their parts, joining them with each other and connecting them with non-living components in such a way that they merge into a botanical-technical entity.

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AUGMENTED REALITY FOR THE HERITAGE
Basilica SS. Medici in Alberobello, a case study

Ilaria Cavaliere

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ABSTRACT
This paper wants to delve into the use of augmented reality to support the architectural heritage, by describing a specific case study on the Basilica SS. Medici in Alberobello. The Basilica was never finished. Its dome at the crossing of the nave is missing, a flat slab is in its place. This also affects its external appearance, the absence of the tholobate makes the building appear incomplete, so much so that the community repeatedly tried to complete the project. Therefore, the creation of an Augmented Reality app (AM) was considered helpful to make the users see the sacred space as it was ideated by its designer, based on a reconstruction process recently developed by scholars and architects from Politecnico di Bari.

KEYWORDS
augmented reality, extended reality, architecture, heritage, virtual architecture

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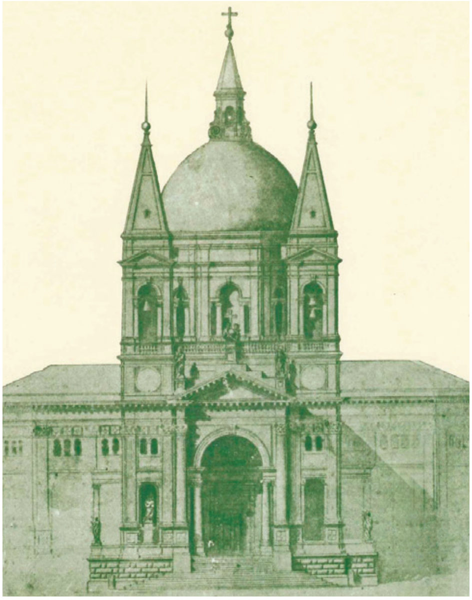
The digital revolution has radically changed the way we face many problems, first and foremost the relationship with reality. The arrival of tools such as augmented and virtual reality – generally called 'extended reality' or 'XR', a term that includes the full range of experiences involving the interaction between virtual and real elements – brings a wide range of possibilities in many contexts, including architecture, restoration and the conservation of historical assets, leading to frequently find newly coined terms such as 'virtual architecture' or 'virtual heritage'. Digital reconstructions paired with extended reality, in all its forms, consent to pre-view – in a more or less immersive and interactive way – a designed space, to view historic reconstructions, interact with objects and artefacts without physically coming in contact with them and, hence, without creating damage, enjoying the monument in otherwise impossible ways and perspectives. All these possibilities make them appealing in the field of actual design, scientific investigation, valorisation and dissemination.

This paper focuses in particular on the case study of an AR app developed by the Author for the Basilica SS. Medici in Alberobello, currently unfinished, because it has no dome. Since this problem is felt by the community, the goal was to provide users (believers and tourists) with a way to fully embrace the sacred space simply and interactively, and also to stimulate a collective consideration and a subsequent debate on the possibility of a concrete architectural intervention. Therefore, this paper, after an introduction to the state of the art on XR research at the international level, will deal with the description of the above-mentioned case study and will describe the app and its development process, and finally will evaluate its innovative aspects and limits.

State of the Art | Augmented reality consists of the implementation of tangible reality with virtual elements, so that users can enjoy a more complex and richer dimension. Therefore, it is a sort of 'integration' of reality with added elements, such as texts, graphs, 3D models, audio, videos, etc. Over the years, the idea of the growing potential of extended reality has led to a substantial increase of the experimentation linked to it, allowing us to consider also the protection and enhancement of Historic Heritage sectors. On the international level, there are increasingly more studies aimed at the evaluation of the worth and effectiveness of extended reality tools (both VR and AR), which are considered a new opportunity to disseminate knowledge (Ibañez-Etxeberria et alii, 2020). Their effectiveness has often been tested and positively demonstrated by focused research and experiments, targeting visitors of historical assets and museums (Tsai, 2019; Trunfio et alii, 2021). This happened and still happens, because the applications of augmented reality are created to increase the curiosity of the users, thanks to a setting that makes them perceived as useful and at the same time fun to use. Basically, the principles of 'gamification' (Swacha, 2021) are put into practice, producing 'serious games', helping to transfer knowledge through a playful dimension that encourages more effective and stimulating user experiences (Mariotti, 2021; Ye, Wang and Zhao, 2021).



Together with the purely informative functions aimed at user involvement, the XR supported by other technologies, such as the laser scanner, can be useful tools for the 'virtual preservation' of buildings and historical heritage endangered by the devastating consequences of climate change. They would allow for virtually preserving aspects that could endure irreversible changes and damages, and for helping to create virtual archives for the transmission of stratified information to future generations (Reaver, 2019). The progressive establishment of augmented reality technologies was supported also by the constant evolution experienced in the last twenty years. Initially, the AR apps required bulky and impractical devices, that have gradually evolved up to becoming smartphones and portable devices, which are now accessible to everyone.

One of the first examples of AR application for the Heritage was created within the project Archeoguide (Augmented Reality-Based Cultural Heritage On-Site Guide), launched in 2001 (Vlahakis et alii, 2001; Vlahakis et alii, 2002). An app for Olimpia archaeological site was created, through which the visitors had the chance to see the geolocated reconstructions, correctly placed on the ruin site. Three different devices were available for visitors (laptop, pen-tablet and palmtop), but only the laptop could exploit all the software's functions. Since this technology is at its beginning, using the app complex equipment was necessary: the images were displayed with special glasses, and the laptop was carried by the tourist in a backpack together with batteries and a GPS receiver and other devices. It was necessary to wear a helmet on which a webcam and a digital compass were attached. Bulky and impractical equipment was the constant of the first AR apps developed between the late 1990s and early 2000s.

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Fig. 1 | Drawing by Antonio Curri for the project of the Alberobello Basilica (source: Pignatelli, 2019).

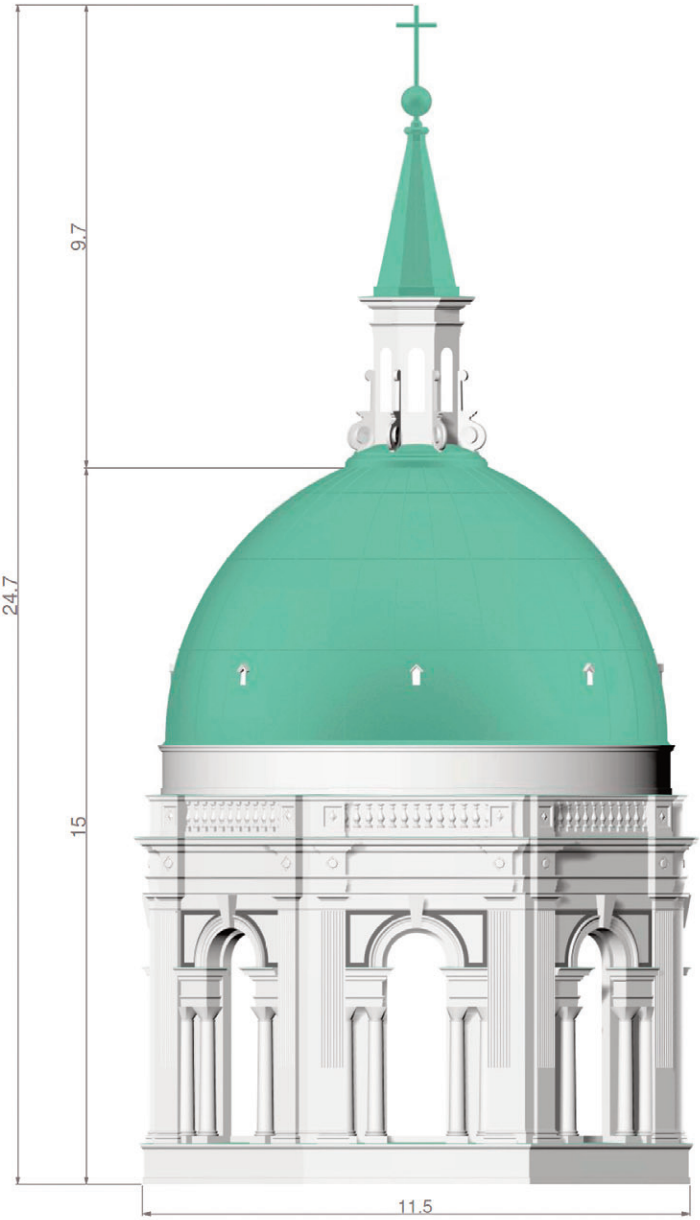
Fig. 2 | Photo of the flat slab at the crossing of the nave and the transept (credit: I. Cavaliere, 2021).

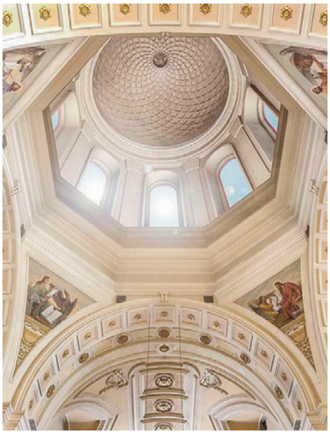
Fig. 3 | Photo of the façade of the Basilica, where the absence of the tholobate is striking (credit: I. Cavaliere, 2021).

Another example is the Augurscope project, developed in 2002 by the Mixed Reality Laboratory in collaboration with the University of Nottingham (Schnädelbach et alii, 2002). It is a dispositive prototype for AR applications, which was made up of a laptop and a webcam assembled together in a special case. The case was mounted on a tripod with wheels to ease the movement from one station to another. Although innovative, it was an impractical and not very versatile object.

With the arrival of smartphones, augmented reality has become a wildly widespread easy-to-use technology, allowing archaeological sites, museums and Municipalities to simplify the integration process of this technology in their Assets, replacing the bulky equipment of the past with apps that anyone can download on their mobile phone. A more recent example, from 2012, was CityViewAR, an app for Android developed after the Christchurch earthquake in 2010 (Lee et alii, 2012). This app was conceived to allow citizens and tourists to view many buildings as they were before the earthquake destroyed or damaged them, through 3D geolocated models, implemented, when needed, with historical photographs and informative texts. Another study, also carried out in 2012, in Norway concerned the use of an augmented reality app called The Historical Tour Guide. Its main purpose was to provide informative texts and historical photographs of cultural assets in Trondheim (Haugstvedt and Krogstie, 2012).

An even more recent example, from 2019, is a study carried out by the Polytechnic University of Milan, that has led to the development of a Mixed Reality (VR/AR) app for the Basilica di Sant'Ambrogio (Banfi, Brumana and Stanga, 2019). It is a complex and stratified work that originated from the study of historical documentation and then





Figg. 4, 5 | Façade and photo-insertion of the new dome (source: Pignatelli, 2019).

shifted to 2D drawings, 3D surveys and an HBIM database. All this knowledge was then moved to the virtual environment, to be viewed partially with a VR visor and partially through AR: reconstructions of the church from different periods, technical drawings, decay maps, etc.

These are just some examples of the countless experiments made on the use of augmented reality. They show the potential of this technology: it gives the chance to see geolocated historical constructions, to virtually preserve Assets that were irreversibly damaged, to simply and easily interact with landmarks and get information on them, to create digital archives containing complex and layered information on a given asset. In general, the common thread underlying these and other experiences is the transfer of knowledge in a new way, involving users more and stimulating their curiosity.

The case study: Basilica SS. Medici in Alberobello | This paper focuses on the Basilica SS. Medici in Alberobello, a monument particularly dear to the community to which it belongs. The cult of Saints Cosma and Damian, which started in Alberobello in the 18th century, has gained great importance over time, in fact, many remodelling and expansion projects of the original worship place were performed where now stands an imposing basilica designed by the architect Antonio Curri, inaugurated in 1885. However, when entering the church, there is a detail striking out: at the crossing between the nave and the transept, the dome was never built. It is present in the original drawings of the project (Fig. 1), but in its place, there is a flat slab (Fig. 2). This affects also the outside, where the tholobate is missing. It should be framed by the two tower bells in the façade (Fig. 3). This absence makes the whole building appear incomplete, so much so that, over the years, the community repeatedly tried to complete Curri's project, but never finished because of a series of static problems that have appeared over time.

Professor Giuseppe Fallacara, together with the Architect Micaela Pignatelli – within the Course of the School of Specialisation in Architectural and Landscape Heritage of the Politecnico di Bari – and the students of the CESAR Advanced Course of the Politecnico di Bari, studied the Basilica and the drawings by Antonio Curri and the design

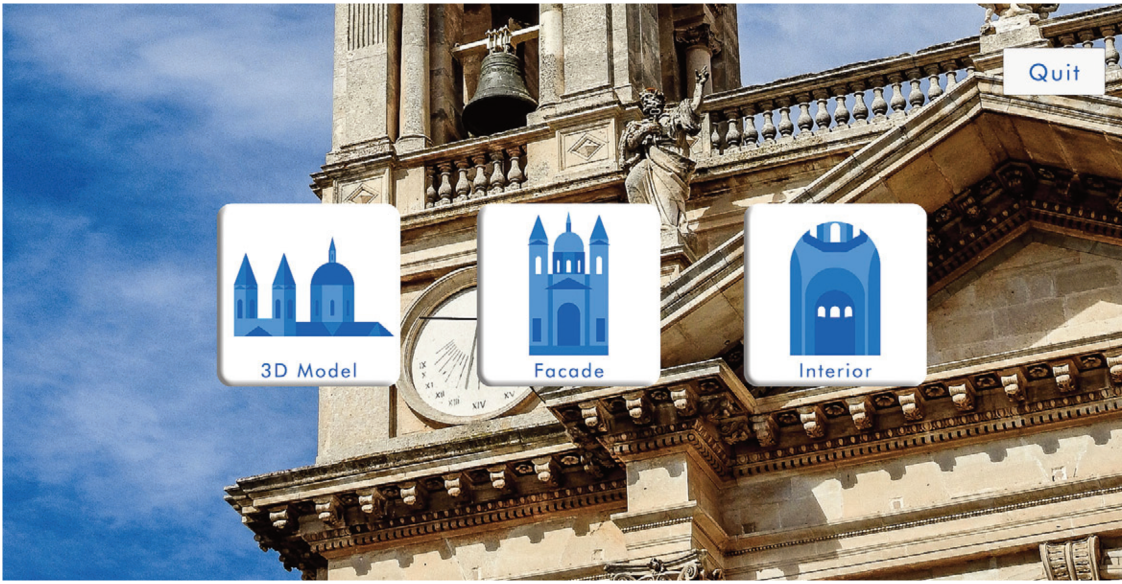


Fig. 6 | Screenshot of the home of the app (credit: I. Cavaliere, 2021).

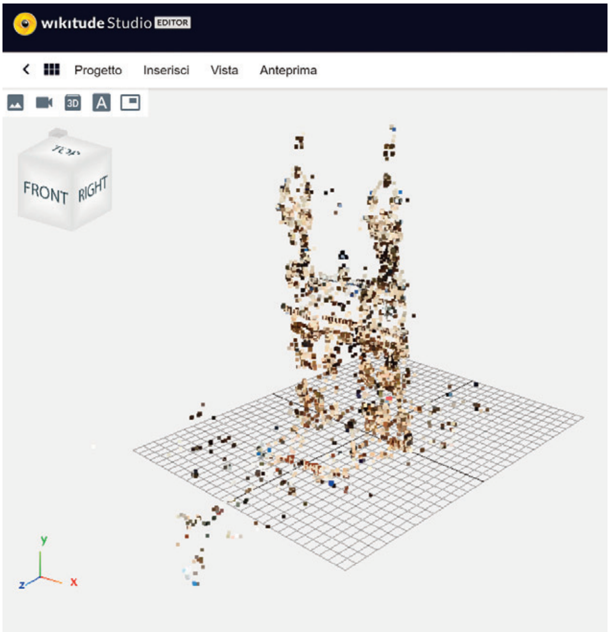


Fig. 7 | Point cloud created with Wikitude Studio (credit: I. Cavaliere, 2021).

of a new dome (Figg. 4, 5). It was created to be as accurate as possible to the original project, with minimal approximations only where the representations were incomplete or unclear – for example in the case of the decorations on the intrados (Pignatelli, 2019). Although the described project was not realised, the interest it generated has led the Author, in collaboration with professor Fallacara, to start thinking about the possibility to enhance its contents and make them available to the community of Alberobello through the potential of new visualisation and design technologies available to architects. In particular, among the extended reality technologies, we decided to use augmented reality because it is currently the most accessible and easy-to-use: to use AM all you need is a smartphone, while virtual reality needs a visor to be enjoyed.

The development of the app | Before starting with the veritable development of the augmented reality app, we thought about its precise aim – to better understand how to structure it – and also about the way to make it known and used by users. As for the first point, the aim is both to give the visitors the possibility to see the dome project on a global scale and to understand how it modifies the sacred space. Therefore, we aimed to obtain a three-dimensional visualisation tool that focuses on the ease of use and immediate communication, which translated into the design of an extremely simple and user-friendly interface, with a limited number of text boxes, photos or other media in order not to make it over-layered.

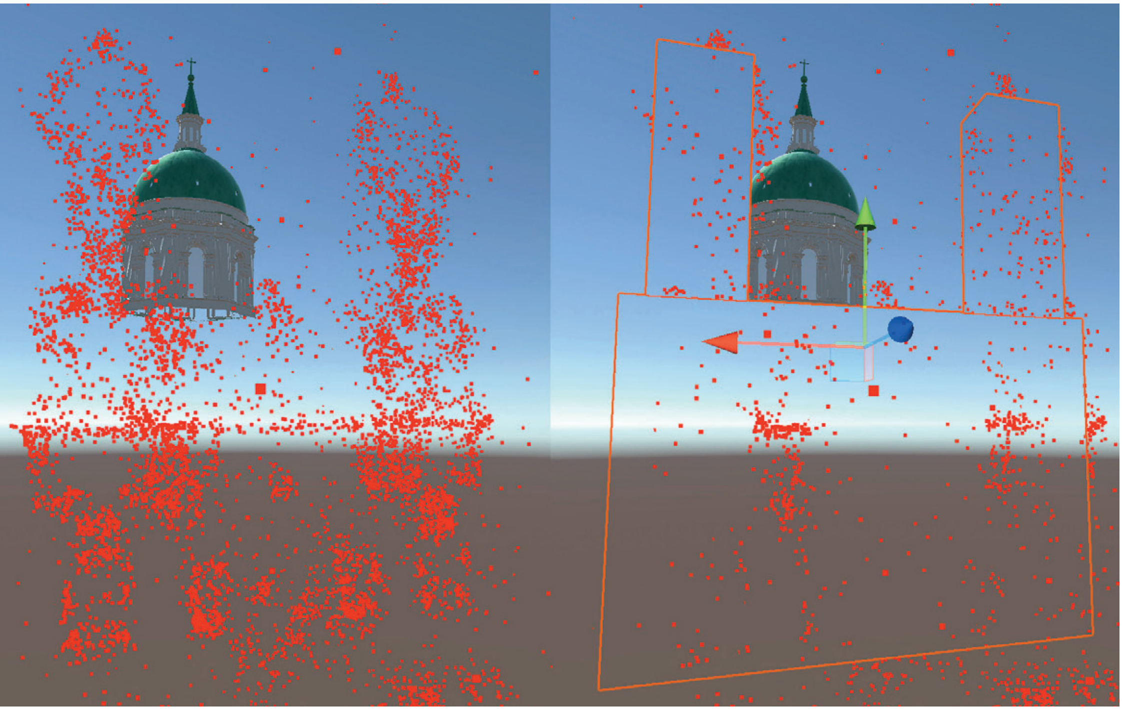
As for the second point, we planned to provide visitors with brochures briefly explaining the project and its context, promoting the app and supporting it. The app was developed for Android smartphones with the 2020 Unity3D graphics engine and the Wikitude plug-in. It was decided to separate the AR experience into three parts: the first consists of globally viewing the dome model, with the possibility to move and rotate it, while the other two parts enable it to be observed correctly positioned from the outside and from the inside, at the crossing of the nave and transept. For each of these possibilities, a ‘serious game’ level has been reserved, that can be selected in the home (Fig. 6).

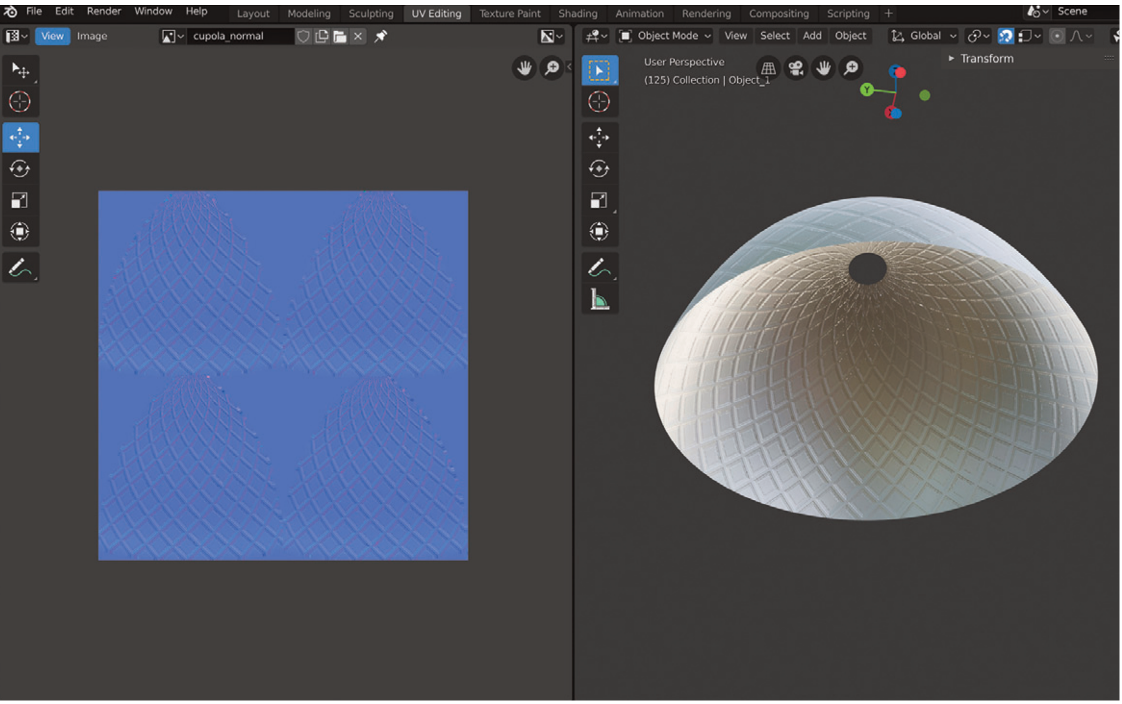
1st level: 3D Model | The development of the first level was based on image tracking, which is a system envisaging the interaction between AR and a 2D image: a photo or a drawing can be printed or viewed on another device, and if you scan them with your smartphone, they become the target for viewing a 3D model or other contents, which are linked to the target, thus following its movements. The image used in this case is the orthophoto of the Basilica, on which appears, correctly placed, the tridimensional reconstruction of the roofing with the insertion of the tholobate that can be studied at 360 degrees simply by moving, tilting and rotating the reference picture to one’s preference.

The 3D model of the Basilica roofing used for this level of the app was created with drone photogrammetry. The photograms were processed with Agisoft Metashape and then the model was optimized through Blender. In this way, it was possible to eliminate the ‘noise’ typical of photogrammetric meshes, the number of polygons was drastically reduced and the topology changed. For the tholobate, it was used as a simplification of the model made with Rhinoceros. The starting 3D model was extremely detailed and included also structural elements that are not visible – for example, the wood load-bearing structure – and, to avoid the excessively large model from affecting the performance of the app, only the external visible parts were kept.

To make the level work properly, Wikitude Studio was used. Starting from the orthographic image of the Basilica, a target was obtained and then imported into Unity3D, where the image tracking was set. To make this level work, it is important having external support from the target image. That is why the above-mentioned brochure can be used. Besides including information on the project and the church, it could show the orthophoto of the Basilica and could encourage to use of the app.

2nd and 3rd Levels: External Façades and Interiors | The second and third levels, are based on object tracking technology, which allows obtaining the point cloud of an object starting from a series of photographs. The point cloud enables the graphic engine to recognize the volumes of the object that, when scanned with the smartphone, become the target for an AR interaction. In this case, it was employed the possibility given by Wikitude to use photos of interiors to convert the simple object tracking into scene tracking, so that the app can recognise the walls and architectural element volumes of the Basilica, in order to view the dome placed where it should be and understand how the perception of the church changes.

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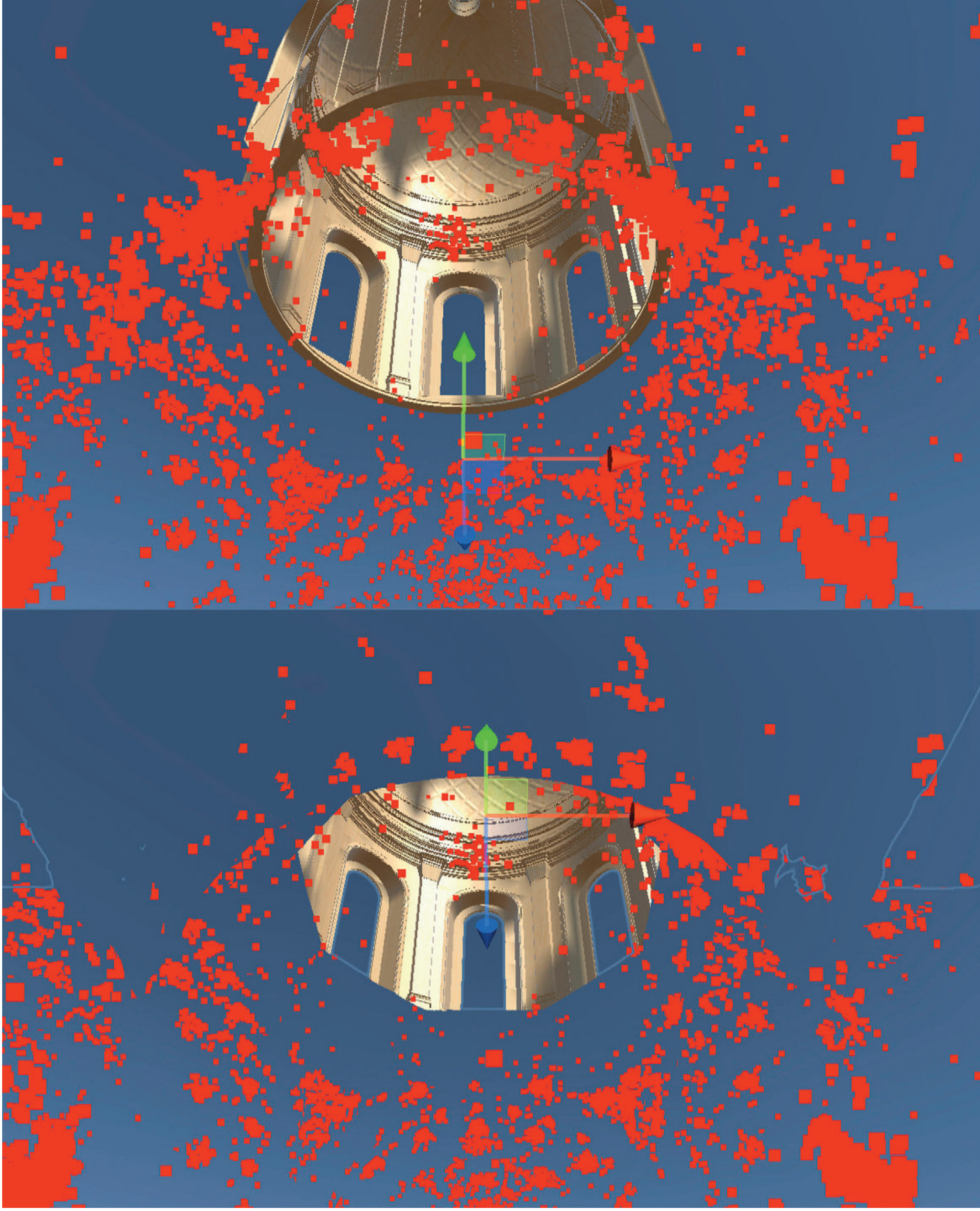

Fig. 10 | View the difference of the tholobate in Unity3D editor before and after adding one occluder before the vault (credit: I. Cavaliere, 2021).

Previous page

Fig. 8 | View the difference of the tholobate in Unity3D editor before and after adding occluders on the façade and bell towers (credit: I. Cavaliere, 2021).

Fig. 9 | View of the dome optimized through Blender thanks to the transformation of the surveys into a normal map (credit: I. Cavaliere, 2021).

Firstly, we dealt with the main façade, that is the south one. Fifty photos were taken – the maximum limit allowed by Wikitude – starting closer to the Basilica and moving on the west and east sides – to get close-up images from different points of view and allowing the software to obtain a three-dimensional reconstruction of the façade – and repeated the process, moving away progressively. Then, the images were processed through Wikitude Studio to obtain a point cloud (Fig. 7), imported as file tracking in Unity3D. In the graphic engine, the tholobate was scaled and correctly placed – the same model used for level 1 – and also the occluders were added before the façade and bell towers. An occluder is a geometry that is assigned a particular material and hides all objects positioned behind it, but is transparent (Fig. 8). The aim is to simulate the real volumes of the Basilica so that they show or hide the dome depending on the point of view.

A similar process was used for the inside: fifty photos were taken of the slab at the crossing of the nave and transept, a point cloud was created with Wikitude Studio and it was imported in Unity 3D. To simulate the dome we have always started from the Rhinoceros model, but this time only the visible parts of the intrados – the inner wood cladding – were kept. To make another simplification, instead of keeping each ceiling coffer, their embossments were turned into a normal map[1] projected on a simple spherical cap[2] (Fig. 9). The outline of the whole vault obtained by photogrammetry was used as an occluder. The 3D model obtained with Metashape was optimized with Blender as it was done for the outside and in Unity3D it was scaled and placed with the dome so that it adapted to the point cloud (Fig. 10). By accessing one of these levels and scanning the Basilica façade or the indoor area with the smartphone, the dome will be displayed at its correct place and it will be possible to overcome the current impression of incompleteness (Figg. 11, 12).

Conclusions | In conclusion, after a thorough analysis of past studies concerning augmented reality and cultural Heritage, it was attempted to give an answer to Alberobello citizens, restoring, at least virtually, their Basilica at its full, producing a creation very similar to the design conceived by architect Antonio Curri. The significant difference between this experience and others carried out in the same field is the final aim of the obtained application: most extended reality app for Cultural Assets aims to give the users objective information and reconstructions or to visually preserve artefacts. Therefore, they are responsible for a 'knowledge transfer' following different modalities from the conventional ones (written panels, audio guides, etc.).

The app described in this paper, conversely, does not aim to convey 'what existed in the past' but 'what could have existed', since the dome presented is not the reconstruction of a real space, but of an idea. Although meticulously based on architect Curri's original design, in some cases, this reconstruction presents unavoidable changes due to the accuracy levels of the design drawings found. The aim is not only to show users a space similar to the one originally designed – partially reducing the sense of

Figg. 11, 12 | View of the dome correctly fitted on the façade and inside with the developed app (credits: I. Cavaliere, 2021).

incompleteness the visitors perceive observing the Basilica inside and outside – but also to start critical reasoning and, consequently, a debate involving the whole community of Alberobello and that concerns also the possibilities and consequences of an actual architectural project for the church. This might lead to considering augmented reality technologies as a tool to foster the involvement of citizens in the field of architectural and urban projects concerning their community. As stated above, the app developed can be easily used by anyone with a smartphone and the possibility to preview the project – without physically touching the artefact – and interact with it, makes it especially fit for purpose.

The limit of this application, however, is especially the type of information conveyed. To be more immediate and clearer for everyone, the information is mostly visual, linked to the need to create a suggestion in the viewer. Because of that, this app is suited to start a debate or, to foster it in the initial stages, because delving into it would require a greater stratification of information, according to models already considered within this paper (addition of photographic documentation, decay and issue maps, etc.). The hope for the future development of this research is to make the app available to the community and evaluate the feedback from the users, by direct observation and the help of purposely prepared forms. As a result, strategies to improve and stratify the app could be implemented, fostering the debate and considerations within experimentation that is not the work of one person only but a shared experience.

Acknowledgements

The survey of the external and internal vault of the church was carried out by the Geologist Gianluca Fallacara. For the first case, a drone was used, and for the second a stereo camera.

Notes

1) A normal map is a colour texture that provides information about the textures of a surface in all three directions of space.

2) For this project, Blender was used, by baking a normal map. It is an operation commonly used to obtain low-poly 3D models – suited for AR, VR applications or in general for real-time rendering – starting from 3D detailed models. The detailed model (called 'high-poly') and the simplified one (called 'low-poly') are superimposed and the textures of the first are 'projected' on the second as a normal map. By implementing this texture to the lowpoly, the embossments will only be displayed as a visual effect, allowing the use of a light model, that does not affect the performance of the project.

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BIM AND IOT FOR AAL
Digital modelling and 4.0 management for care and assistance services

Anna Mangiatordi

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ABSTRACT
The transition towards digital healthcare is considered by the EU as a successful approach to improve assistance access and care quality and to increase the efficiency of the healthcare system. The use of BIM, IoT technologies and ICT applications in the Architectural Engineering and Construction Industry (AEC) can provide important benefits to the implementation of effective design and management processes, revolutionising the design of buildings used to provide care and assistance services. Starting from the comparison with some design experimentation experiences carried out during the pandemic, this paper deals with the development of a digital model of Ambient Assisted Living (AAL) where the BIM method is used to facilitate the interoperability of the data concerning IoT devices and the management of Facility Management activities linked to it.

KEYWORDS
ambient assisted living, building information modelling, healthcare design and management, internet of things, industry 4.0

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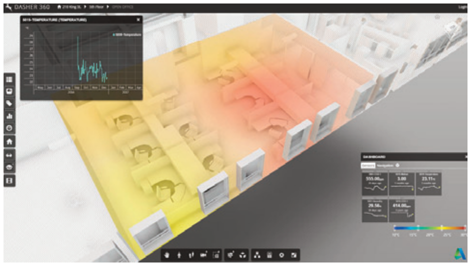
The transition towards digital healthcare is considered by the EU recent funding programs and research projects[1] as a successful approach to improve healthcare access and quality and increase the efficiency of the healthcare system (European Commission, 2021). Digital technologies are an effective solution to overcome the post-pandemic Covid-19[2] crisis, allowing significant economic savings on public expenditure and helping to address social and health challenges related to the fragile and ageing population (European Commission, 2020). Facing this transformation, the most physically and economically fragile people could benefit from many advantages linked to 'digital health', such as better access to services and a quick response to the need for care and assistance.

The pandemic has led to a progressive acceleration of the digital processes, requiring a need to invest and innovate, within a consistent and structured development Plan, to quickly make up for a years-long – at least in Italy – delay. The modernisation and redesign of hospitals and care facilities are necessary for outdated buildings, technology and electromedical equipment (Arbizzani, 2021). It is part of a greater economic and social recovery plan, involving different sectors. The implementation of financial tools for the recovery after the pandemic – as the Next Generation EU[3] in Europe and the PNRR (National Recovery and Resilience Plan)[4] in Italy – encourages the development of structural and precise interventions on the existing building heritage and the creation of new buildings, useful to boost the healthcare network. It also envisaged the reconfiguration of spaces to accommodate new equipment and technological devices to facilitate the provision of advanced health and assistance services aimed at fragile users, particularly people with impairments and the elderly.

Implementing the use of state-of-the-art plant equipment and digital technologies in buildings is as important as implementing multidisciplinary integrated design methods and tools, involving more workers with different skills within the same industry, with the aim of reaching a higher quality in the whole building process (Arbizzani and Clemente, 2020). The use of BIM (Building Information Modelling) methodology could give a strong boost to the creation of complex buildings and management of advanced services, representing a shared tool capable of managing building processes (Russo Ermolli, 2018) with highly informative content.[5]

The focus on some experimental design experiences carried out during the pandemic shows the need to accelerate this evolution, depending on environmental and technological factors that could influence the speed of construction with shared project operations. The results of these experiments show the use and effectiveness of the BIM tools during planning and building in emergency conditions. One of the most innovative and potentially promising aspects is the possibility to control the whole design process with the use of informed modelling methodologies and the development of interoperable platforms. The maturity reached by the IoT (Internet of Things) technology of exchanging data between commonly used objects, together with the ICT (Information and Communication Technologies) platforms and the BIM tools of syn-

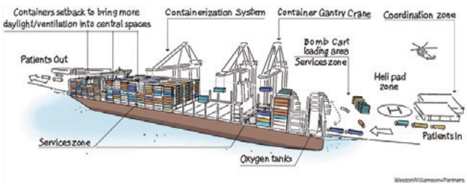


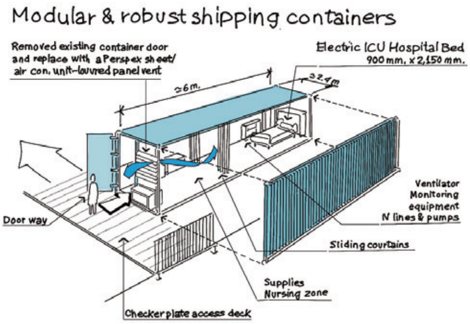
Figg. 1, 2 | The DASHER project by Autodesk links the BIM model to IoT technologies. The sensors located in the environment allow monitoring of a building's performance, including lighting, the movement of dwellers, and the level of carbon dioxide in the environment. Navigate in the BIM model through an ICT platform allows accessing data monitored by IoT devices, making certain specific conditions in the environment, such as temperature, or the path of dwellers, immediately visible (source: autodeskresearch.typepad.com; dasher360.com).

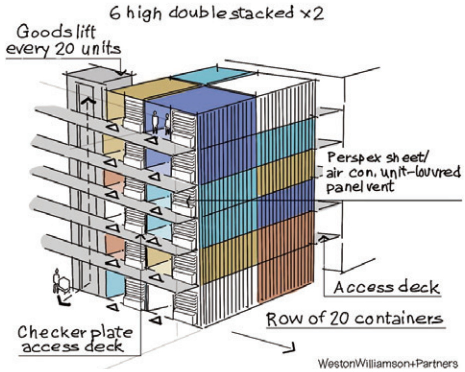
chronising pieces of information coming from different sources (Tang et alii, 2019) can allow to experiment innovative methodologies to supervise the project (Figg. 1, 2), and enabling innovative digital services for care and assistance and related Facility Management activities.

In this context, the paper deals with the development of an AAL (Ambient Assisted Living) for fragile users, where the digital representation is used as a tool to ease project management and interoperability of the data concerning a range of IoT devices placed in the environment. Through the modelling of four housing units for the elderly and the creation of a data-set of parameters and attributes associated with IoT sensor technologies, a structured model of digital facilities was defined. The logic of relational databases, interoperability and informative enrichment was used as an effective device to trace heterogeneous data, envisaging the accessibility to information through a web services platform and the replicability and extension of the BIM model and different use contexts. The innovative and original aspect of research is the experimentation with innovative ways to define the project and to handle details through the implementation of categories, objects, parameters and features belonging to AAL components for care and health, traditionally not planned by default BIM models.

Pandemic Emergency, Architecture for Health and Digital Innovation | Faced with the quick and uncontrolled growth of patients with severe respiratory syndromes, hospitals had considerable difficulties to adapt the number of intensive care units to the unforeseen necessity dictated by the pandemic. The health Emergency has required, in particular in the first stage, the creation of emergency hospitals with tents and temporary set-ups – not always effective for the safety of health workers – then replaced with the construction of new wards or the renovation of existing ones. In some countries, compounds were made with containers equipped with tools necessary to care and assist and bio-containment systems to ensure maximum protection against any outdoor con-





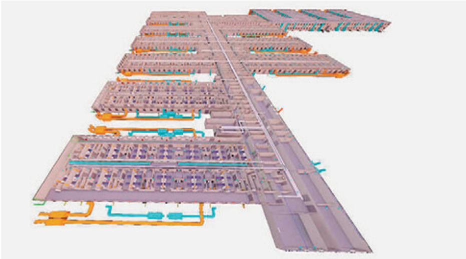


Figg. 3-7 | The Weston Williamson + Partners project represents a visionary study on how container ships could be transformed into huge hospitals and reach by water the cities mainly affected by Coronavirus, in particular those with less access to healthcare. With about 2000 beds, each container is a modular intensive care unit (credit: Weston Williamson + Partners, source: dezeen.com).

tact. At the international and national scale, guidelines were created (WHO, 2020) and project experiments were undertaken (Figg. 3-7) aimed at sustaining the main need to limit in a short period and through architecture, the health emergency.

Wuhan Huoshenshan Hospital is a temporary structure made in the epicentre city of the pandemic, on an area of approximately 34,000 square metres, designed in just 24 hours and built in about 10 days, to treat patients infected with Coronavirus (Fig. 8). The hospital, with about a thousand beds, has two levels, made with off-site modular units of reinforced concrete and steel structural supports. The containers have spaces for intensive unit care and hygienic facilities, with finishes that guarantee healthy, cleanable and durable conditions, while medical equipment cables are concealed in internal partitions. The use of the BIM method (Fig. 9) has allowed, from the conceptual phase up to the building stage, the shared participation in the project choices by stakeholders (such as government and municipal representatives) and a multidisciplinary work team (such as designers, doctors, nurses and workers, etc.) that took care of the coordination of the work (Peng, 2021). The digital BIM representation was effective to create a modular design, useful for standard production and manufacturing of off-site components, and the real-time visualization of the project, allowing shared controllability of the model and its parts in the design stage and limiting possible mistakes in the building stage, with reduced building site deadlines (Fig. 10).

The Leishenshan Hospital was created in the Jiangxia district in Wuhan, a space of approximately 220,000 square metres for a total construction area of almost 80,000 square metres (Fig. 11). The hospital is divided into three functional areas, organized in dirty-clean paths: the living area for the medical staff; the logistic area for the decontamination of ambulances and waste and wastewater treatment; the space destined to medical care (Figg. 12, 13). The project was organised based on modularity: the off-site unit (with standard dimensions of 6.0 x 3.0 x 2.6 m or 6.0 x 2.0 x 2.6 m) was made by an isolation room (equipped with all the necessary medical and plant engineering equipment) and a bathroom that becomes a filter between the two transit areas for doctors and patients (Figg. 14, 15). The model of the building was defined by the BIM methodology (Ling-Kun et alii, 2021), and has allowed, in the design stage and during construction, to control and achieve optimal performance standards (Figg. 16, 17). For the Leishenshan Hospital, the use of BIM tools was useful not only to save as much time as possible, but also to simulate space ventilation, and hence to foresee the possible airborne transmission (Fig. 18) during operation stages.



Figg. 8, 9 | Wuhan Huoshenshan Hospital is the world's first large-scale temporary facility built in record time to accommodate people infected with Covid-19. Designed in 24 hours with BIM methodology and created by CITIC Architectural Design Institute and China Construction Third Engineering Bureau, by a team of approximately one thousand five hundred workers and five hundred construction machines, at the request of the Wuhan municipal construction unit (source: redshift.autodesk.it; credit: CITIC ADI).

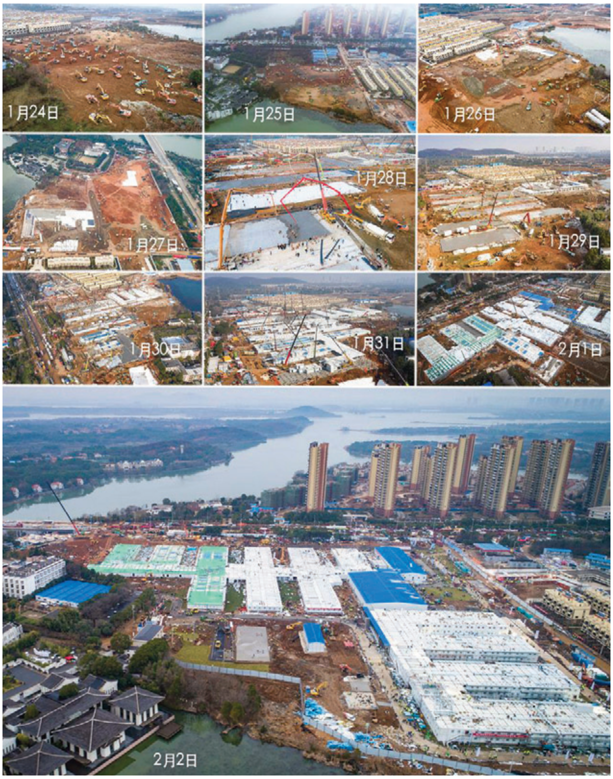
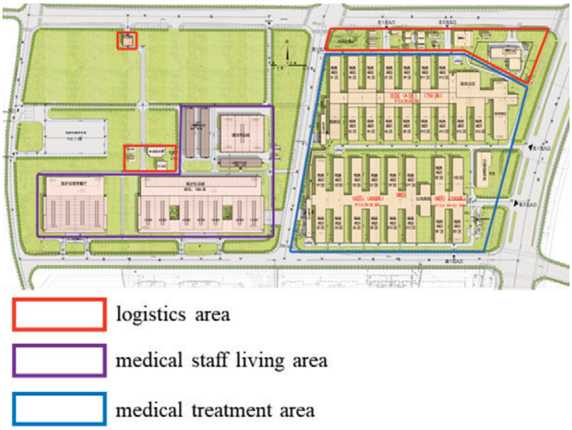
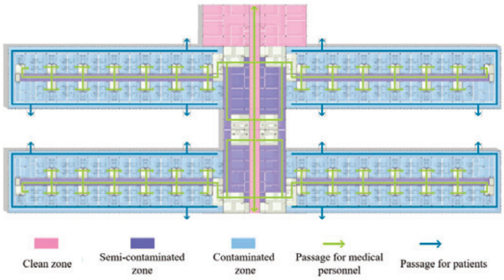


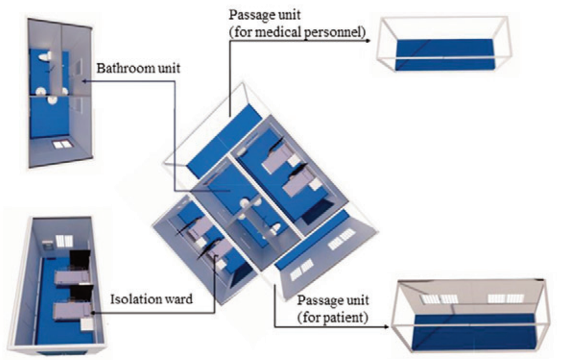
Fig. 10 | Building site stages of the Huoshenshan Hospital in Wuhan, built in 10 days (source: mfa.gov.cn).

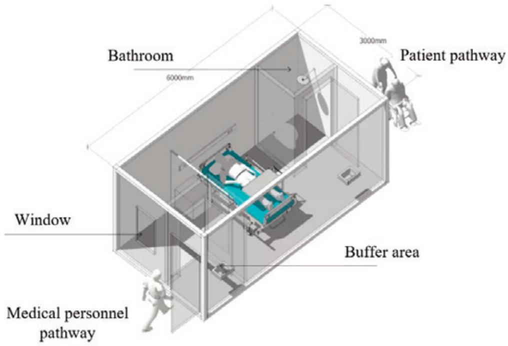
Fig. 11 | Global view of off-site modular units in the Wuhan Leishenshan Hospital project (source: archdaily.com).

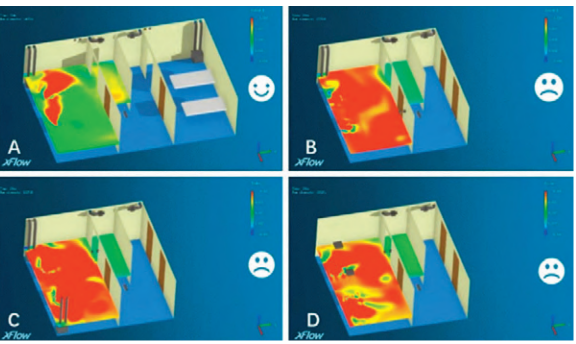
The CURA Pods project (Connected Units for Respiratory Aliments) was created by an international group of practitioners (architects, engineers, doctors, nurses, etc.) led by the architect Carlo Ratti, as a temporary module to handle intensive care resulting from Covid-19 infection (Fig. 19). The model is a container (2.44 x 6.05 x 2.59 metres in height) combinable and transportable. The container was made of aluminium composite panels consisting of two sheets with a polystyrene core, with a negative pressure bio-containment and an extractor filtering the air to avoid external contamination. Through two glass windows, the healthcare workers, and families, can watch the patients. The off-site modules can be assembled with inflatable corridors (3.00 metres in depth x 3.20 metres high), used as warehouse and dressing room, capable to take on multiple configurations that can be extended as needed, from 4 to 40 beds (Figg. 20-25). The model was developed with an 'open source' methodology with the cooperation of an international task force[6], made up of many international professionals, each one with their knowledge, has helped to set technical specifications and project requirements. The architectonic representation of the base module, with equipment, furnishings and facilities, was made with the BIM software Edificius® (Fig. 26). It produced a three-dimensional digital model of a hospital intensive care unit also to be used as a data container or 'digital











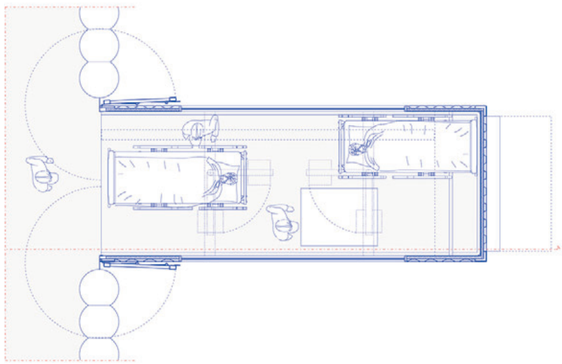
Figg. 12-18 | Functional layout and BIM model of the Leishenshan Hospital in Wuhan were created also to simulate and prevent viral contamination in modular units (source: sincedirect.com; credit: CITIC ADI).

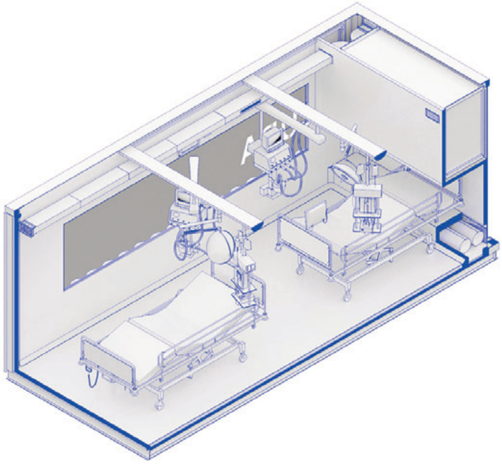
Fig. 19 | Scenario of insertion of the CURAPods project in Milan, urban context (source: archipanic.com).

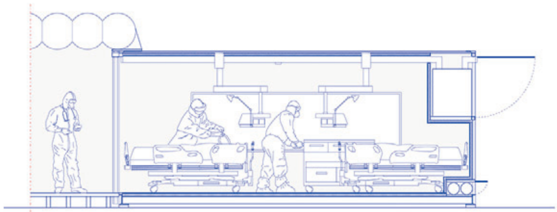
twin'[7], capable of carrying out any simulations to be applied to the real world. The BIM model, uploaded on a usBIM.platform®, is accessible online in each stage of the service life cycle of the building and provides access to every information (data, data sheets, properties) associated with each object in the model (BiblusBIM, 2020). The BIM platform is a real data sharing environment and gives the possibility to use advanced functions, allowing through a specific Cloud infrastructure, to handle online the digital model and to carry out simulations with Virtual Reality and Immersive Reality tools.

BIM and IoT for Ambient Assisted Living | The below-mentioned experimentation[8] was developed when we were still unaware of the transformations that the pandemic emergency would create in the health and assistance sector, hence in the Engineering and Construction Industry (AEC), and in the global society. However, some considerations were under development, and although they refer to a different time context, are very much in line with the needs of the unique moment we are living in. The need to accelerate the digital transition, computerise building processes, and make health and assistance services accessible remotely, are fully applicable to the solution of some current problems, such as social isolation, emphasised by the imposition of physical distance or home care and nursing treatments, with direct positive effects on the physical and mental health of particularly vulnerable people, such as the elderly (MASS, 2020).

The study has proposed an Ambient Assisted Living (AAL) digital model for the elderly, whose digital representation was used as a supervision tool and as a methodology to ease the interoperability of information concerning planned management of activities and user behaviour, considering the introduction of IoT devices in the environment and the information and communication infrastructure linked to it. The study has







Figg. 20-25 | Graphic-technical drawings of the digital model of the CURAPods project, Carlo Ratti Architetti Associati (source: dezeen.com).

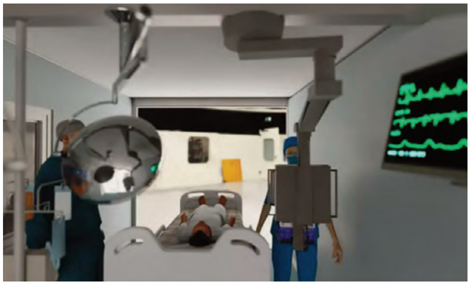


Fig. 26 | BIM at the service of emergency, rendering of the CURAPods project created with the BIM software Edificius® (source: bim.acca.it).

followed a parametric approach to modelling and Facility Management in health and assistance fields: through the creation of a data-set of parameters and attributes associated with IoT sensor technologies, a structured model of digital facilities was defined to control the AAL, starting from the creation of its digital model. Through the modelling of four house units for the elderly, optimised design solutions were investigated, starting from the correct spatial layout and the introduction of IoT technologies for energy management and environmental comfort, health monitoring and personal assistance, safety control and ensuring the safety of the elderly user (Fig. 27).

The structure of the model is based on an 'information database' within the BIM model including all the data referred to the housing module and the Artificial Intelligence systems (e.g. sensors and actuators) in it (Fig. 28). The monitoring infrastructure is based on a network made of various smart devices, whose informations, analysed and explained via a 'middleware', can be collected in a 'server' to enable the subsequent update of the digital model and the interaction with a 'web platform' of services related to the person, the building and the analysed organisation. Starting from spatial information, the 'relational database' (Fig. 29) in the BIM model was implemented with the data concerning the sensor technologies and automation systems in the digital environment (e.g. identification, quantity, position, parameter to be monitored, etc.) and used during the design development stage to identify the single components to trace information on the devices added in the house modelling (Fig. 30). Each element of the project is linked to an identification tag that enables to unambiguously recognise the single components, new parameters and characteristics are linked to them (e.g. ID, Date/Time, Location, Parameter, Status, Unit of measurement, Value, etc.; Fig. 31), whose information, tracked by devices, can populate the database operating within the digital model according to bidirectional informative fluxes.[9]

The information on the model has then been defined with a 'semantic structure' (Simeone and Cursi, 2016) based on the standard format IFC[10] (Industry Foundation Class) to be shared with each stakeholder[11], to enable the interchange of information not only between different softwares[12], but also with data management platforms. The classification of each device in the .IFC format, defined within the general category 'data devices', was useful to recognise the smart device category according to a stan-

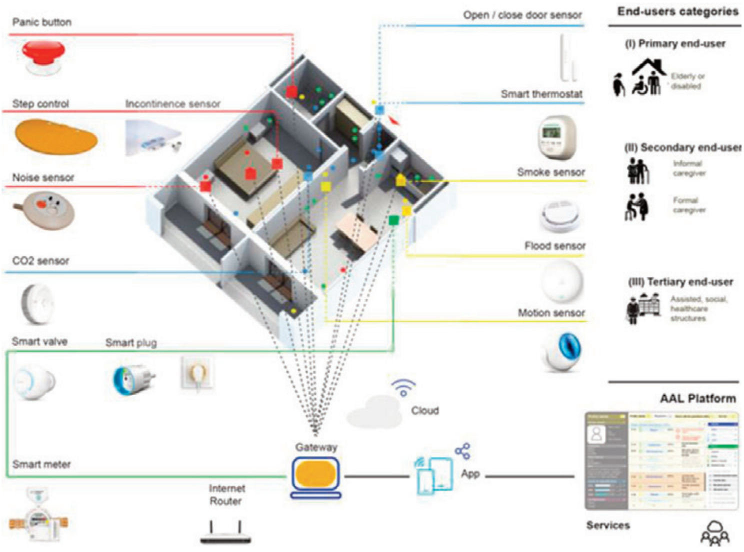


Fig. 27 | Model of the assisted house (AAL) for fragile users, IoT technologies and interaction with the ICT service platform (credit: A. Mangiatordi, 2020).

dardised coding (IfcSensor) linked to a specific element (IfcSensorType) recognized as 'sensor'. Each device was then added to the BIM model as a new component of the category 'data devices', giving each element the relative propriety (IfcSensorType_PropertySet; Fig. 32). The data collected in the .IFC format can be accessed through external applications or functions that can interact with the BIM model, such as to make it interoperable. For example, they are useful to reprocess information needed for medical records or able to simulate emergency events occurring in real-time or to interact with different service platforms, and the software applications normally used for Facility Management operations.[13]

The access to the data occurs in a common BIM environment[14], as an information container – geometric and semantic – concerning the housing model. The data referred to the devices, traced and combined in the BIM model, can be analysed for different purposes, to enable energy, welfare or health services, as well as being displayed and made accessible to users for different purposes. The structure of the model can be shared and used by every worker of the process, both during the project stages and the operational and management stages, within the whole building life cycle. The use of a web platform can facilitate the visualisation of devices in the environment and the trend of parametric variables over time (Fig. 33). The implemented digital process is particularly effective because of the future possibility of accessing ICT/IoT services for the Facility Management referred to the person and built environment, manageable also remotely.

Results and Future Developments | The study, carried out during the research, has led to the development of a computer data simulator: the 'asset' of prepared BIM cate-

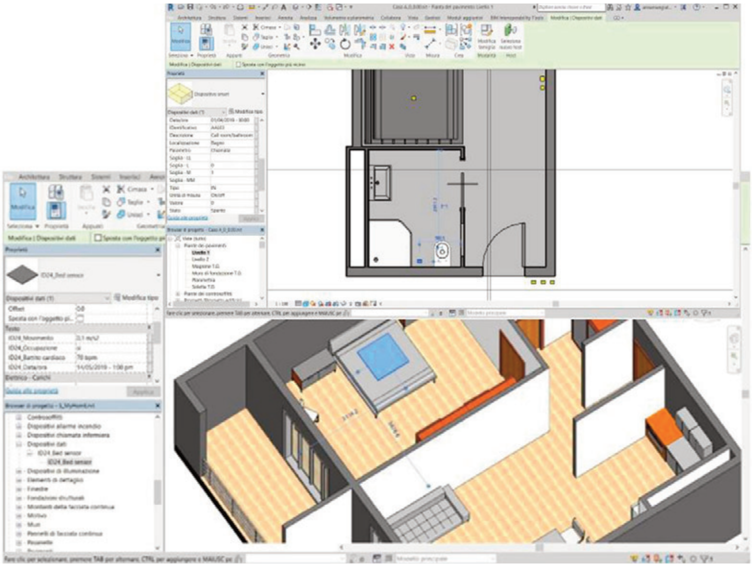


Fig. 28 | Digital model of an assisted house unit (AAL) for fragile users created with Autodesk Revit® software (credit: A. Mangiatordi, 2020).

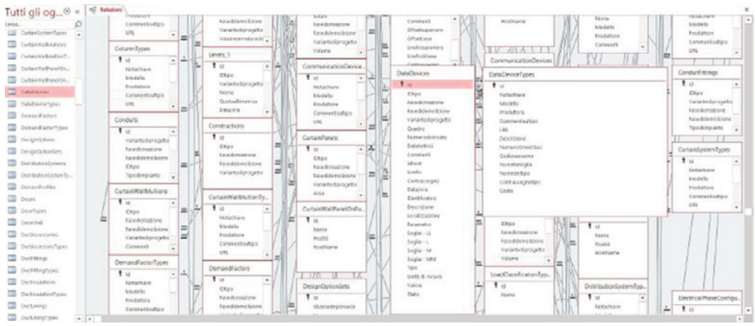
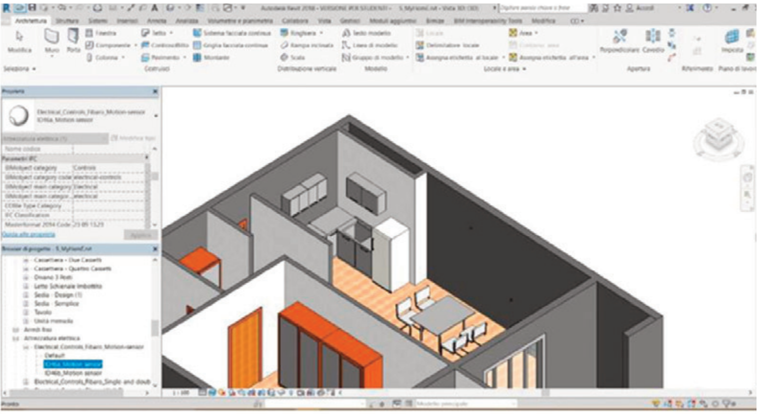


Fig. 29 | Relational database structure at the base of the digital smart model implemented (credit: A. Mangiatordi, 2020).

gories referred to a selected set of housing units, IoT devices and parameters concerning different reference scenarios. The project has used the parametric and interoperable nature of BIM tools, allowing the development of an evolved digital model, used in the design stage to reduce error and trace information concerning IoT devices placed in the environment. The harmonisation of data according to common and open formats (Dave et alii, 2018), makes them easily accessible, quickly available, sharable, updatable and implementable. This aspect provides for better adaptability of the model to specific project needs and requirements on particular environment conditions (e.g. temperature, CO_2, etc.), danger (e.g. the user falls, goes away from home, etc.), safety (open door, presence of gas and fumes), and health control (e.g. checking body temperature, weight, etc.) of the user.

The web platform will enable to view data concerning the devices, useful to activate preventive or corrective response actions to specific environmental condi-



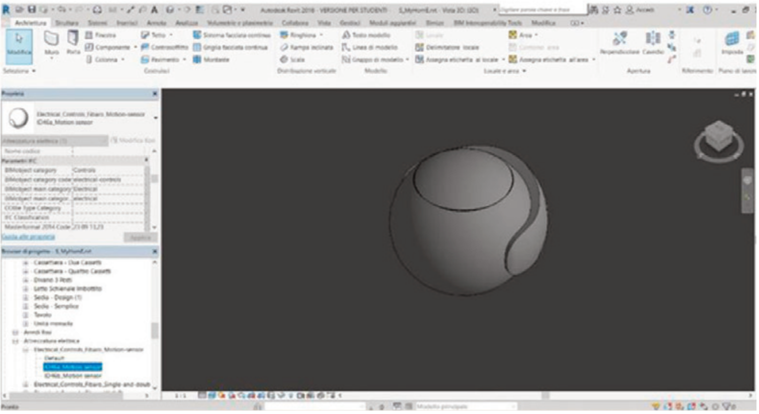


Fig. 30 | Modelling of a housing unit and placement of a smart device (example configuration) in the BIM platform of Autodesk Revit® (credit: A. Mangiatordi, 2020).

tions (e.g. control of indoor comfort conditions and air quality, the zoning of rooms according to certain functions, etc.) or specific needs of the users (e.g. displaying messages and alarms, responding to specific required services such as dressing, cleaning the room, vital signs monitoring, etc.). A future stage of the ongoing research will concern: the development of a systematised framework of environmental and technological requirements for elderly housing considering the renewed needs that emerged during the pandemic; the optimisation of housing models following flexibility and adaptability criteria in time, by adding filter and connection spaces, common spaces to stimulate new forms of collectivity and social interaction; the extension of the model to the entire building or district, including the integration of outdoor and neighbourhood spaces, by using interoperable BIM/GIS procedures; the optimisation of the interaction between web platform and BIM model, by testing further applications, devices and functions in addition to those created so far.

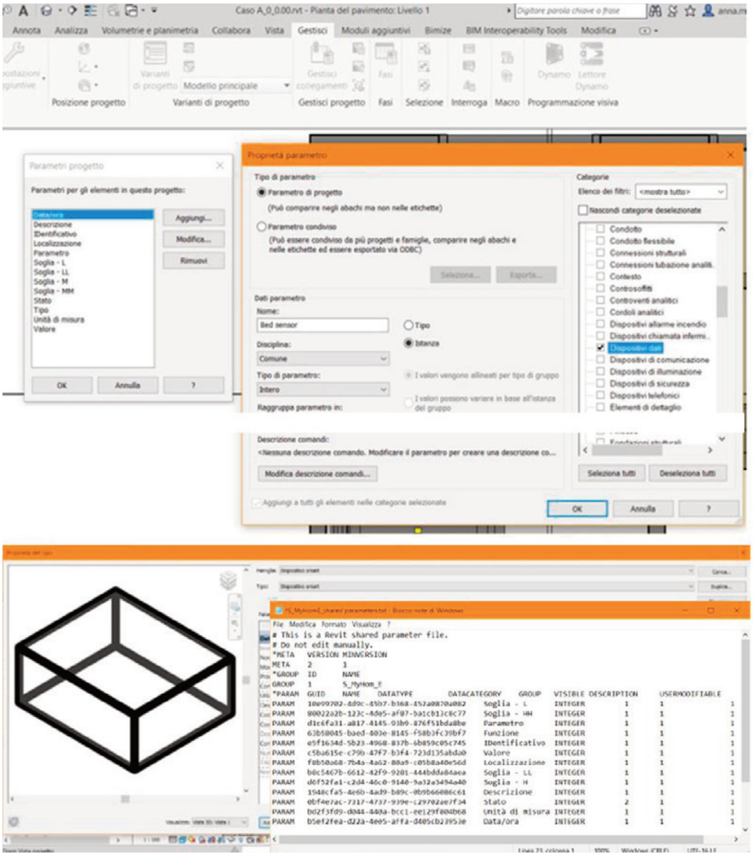


Fig. 31 | Shared project parameters applied to smart devices: an example of configuration (credit: A. Mangiatordi, 2020).

The design approach adopted has led to the definition of spatial configurations, in which the technological equipment can also be implemented at a later stage, imagined as an ‘open system’ continuously updatable and implementable. The modelled technical elements could allow the right placing and integration, even in the future, of other sensor devices aimed at monitoring vital parameters: emergency and care supplies and equipment. The results achieved with this research, although incomplete and referred to a few possible applications, are an example of the potential that the most advanced digital tools could offer in optimizing the design and management process of future building types and organisations in the health and assistance sector. The digital model created, although referred to the specific case of AAL for the elderly, is currently undergoing further optimisation, adaptable to future applications extendable to other building types in the healthcare and assistance fields and to different user categories, opening up the research to possible new experiments in this field, important for the building industry.

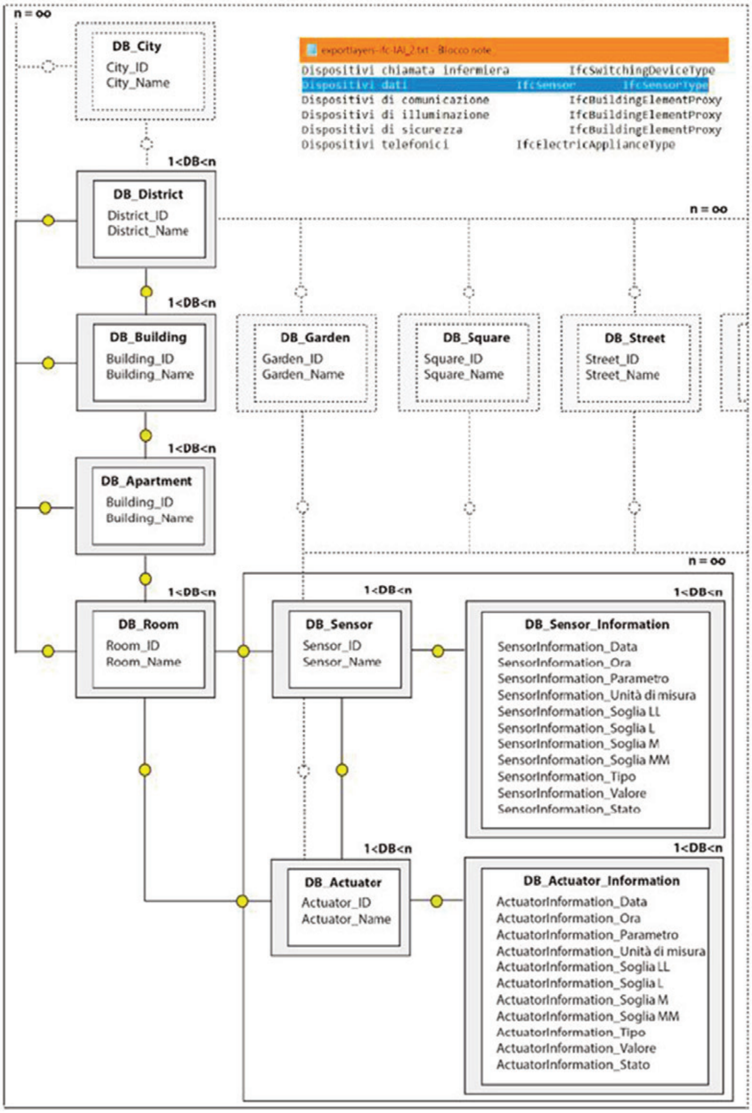


Fig. 32 | Organization and structure of the BIM model: a connection between spaces, smart devices and parameters to be controlled (credit: A. Mangiatordi, 2020).

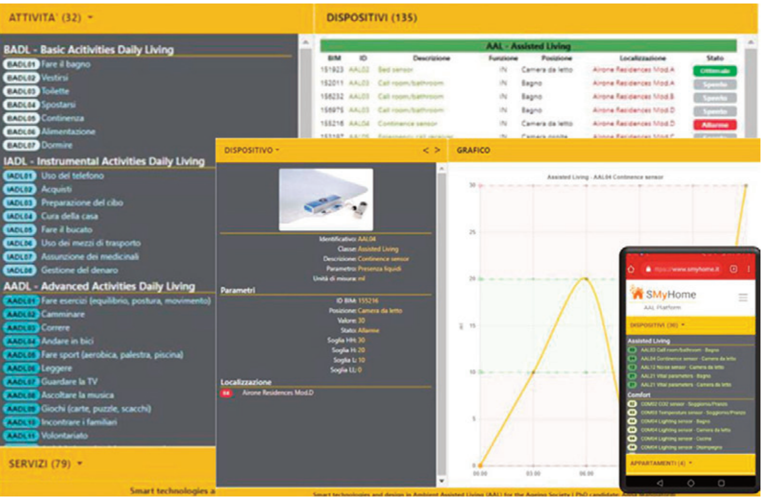


Fig. 33 | Graphical interface of AAL platform and devices display: an example of configuration (credit: A. Mangiatordi, 2020).

The perspectives outlined in this sense are useful to trace the path that the whole industry could follow on processes and product digitisation to reach new sustainability goals. They are useful also to improve the efficiency and productivity of workers in the sector and to ensure health and safety for users in the environment, within a new dimension of relations and contamination between real and virtual, material and immaterial, analogue and digital (Deng, Menassa and Kamat, 2021), benefiting from the value potential that would result from the interaction between BIM tools, Artificial Intelligence systems and ICT applications for handling health and care services and the performance of associated Facility Management activities (Ghaffarianhoseini et alii, 2017).

Conclusions | Since the early stages of the pandemic, architecture has represented a useful means to support first-line health care providers, facing unprecedented clinical demand. Building specific hospitals and assistance facilities, made up of modular or off-site units, has made the workers in the building industry true emergency responders, offering high-quality projects in exceptional circumstances. The experimental examples of newly developed practices, although referred to as a temporary situation, show that is possible to create in a short time architectures for environmental and technological high-performance health and that the digitisation and informatisation of the built environment are the best paths to overcome future crises. In this context, the role of the designer is still to improve, through architecture, the quality of life for people, using project tools and methods now evolved, but adapted to the current and future needs of the community. In this scenario, the collaborative approaches to the design can be the most immediate response to the requests for first aid and assistance to the needs of particularly vulnerable people, such as sick or chronically ill people, people with impairments and the elderly (De Giovanni, 2018). Another one is the use of methodologies typical of computer modelling to facilitate the creation of advanced building models in a short period and at an affordable cost.

However, digital innovation can contribute to further improving the effectiveness of the health or assistance service, creating new opportunities for physical and social interaction, enhancing user experience and improving work conditions of hospital or social care workers. As highlighted in the mentioned research case study, the massive diffusion of digital technologies and the use of BIM tools and computer data, accessible through web-based platforms, could contribute to improving some services, such as setting up the electronic health record, filling in medical records, 3D navigation in hospital or assistance environment, the use of environmental and energy consumption monitoring equipment, security control and patients or fragile users health control, particularly suited for the emerging needs imposed by the pandemic.

Therefore, pushing towards the digitisation of the healthcare sector and the reliance on telemedicine find fertile ground in this particular emergency, but adapt perfectly to the prior need to accelerate computerisation processes of the built environment and health and assistance services. In this diffused and pervading transformation, the contraposition between the real analogic world and the virtual digital world is increasingly weaker, reducing the limits and overcoming the boundaries of relationship spaces, defining new interaction relations between humans and machines, through hyper-connection and constant sharing of information in real-time (Campioli, 2020).

Notes

1) In line with the research purposes of Horizon Europe, Pillar II – Global Challenges & European Industrial Competitiveness (Cluster 'Health', 'Digital Industry and Space'), via specific programs such as EU4Health, and the sustainability aims of Agenda 2030 (SDG3 'Good Health and Wellbeing', SDG7 'Affordable and Clean Energy', SDG9 'Industry, Innovation and Infrastructure', SDG11 'Sustainable Cities and Communities') the use of robotic systems, the use of advanced devices, the introduction of smart components and automation systems in buildings, the creation of proximity networks and infrastructures for telemedicine and healthcare, and the digital transition through investments in research and development are envisaged. For more information, see the websites: ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en [Accessed 16 July 2022]; unric.org/it/agenda-2030/ [Accessed 16 July 2022].

2) On 30 January 2020, the World Health Organization declared a 'Public Health Emergency of International Concern' the Coronavirus epidemic diffused after China reported a cluster of cases of pneumonia of unknown aetiology on 31 December 2019. Due to the extent and ease of contagion and the containment measures taken so far, the state of a health emergency, still ongoing, was extended temporarily until 31 March 2022. For more information see the WHO, 2021 report.

3) Next Generation EU, a tool for recovery, aims to 'better rebuild', following the support of the green and digital twin transition in the health and assistance field, to ensure personalised and effective care and a comprehensive digitisation of health systems. For more information, see the website: ec.europa.eu/info/strategy/recovery-plan-europe_en#nextgenerationeu [Accessed 16 July 2022].

4) Within the PNRR 'Mission 5 – Social Inclusion', specific funds were allocated for renovation projects of assisted living residences or nursing homes for elderly and the creation of new housing forms, even temporary, to prevent institutionalisation, as well as financial obligations to support home-based care and assistance activities for people with impairments and the elderly. The PNRR 'Mission 6 – Health' aims in particular to strengthen proximity networks and intermediate facilities for telemedicine and assistance, directing innovation and research towards the digitisation of the Italian National Health Service (SSN). For more information, see the website: governo.it/sites/governo.it/files/PNRR.pdf [Accessed 16 July 2022].

5) The Italian Ministerial Decree No. 312 of 2 August 2021, amending the previous Italian Ministerial Decree No. 560 of 1 December 2017, provides specific measures for interventions on buildings and infrastructures useful to the implementation of the funds provided for in the PNRR. It envisages bonus scores for the use of BIM in design, according to criteria that may favour the development of innovative methodologies for project control and management, together with aspects of information model management, as well as the use of augmented and virtual reality tools, sensor-based monitoring systems, or electronic methods and tools aimed at reaching environmental sustainability goals (also following Green Public Procurement principles). For more information, see the website: mit.gov.it/normativa/decreto-ministeriale-numero-312-del-02082021 [Accessed 16 July 2022].

6) The CURA Pods project was created with the support of the World Economic Forum – Covid-19 Action Platform and Cities, Infrastructure and Urban Services Platform, an international team of expert professionals. For more information, see the websites: carloratti.com/project/cura/senseable.mit.

edu/cura-configurator/andcurapods.org/ [Accessed 16 July 2022].

7) A Digital Twin is a digital representation based on the data of something existing typically in the real world. The immediate benefits of the creation of a Digital Twin are embedded digital technologies. By sharing data and information in real-time they can allow to save great quantities of energy and resources, and to access to innovative digital services, creating new improvement, productivity and creativity opportunities for the users, and optimising the functionality of buildings through control and monitoring processes. More information on the Digital Twin concept can be found in the ARUP, 2019 report.

8) The paper presents the results of the PhD Thesis written by the Author (Mangiatordi, 2020), together with some university research carried out in the PDTA and DIAP Departments of 'Sapienza' Università in Rome, still ongoing: 1) 'Smart Technologies and Design in Ambient Assisted Living (AAL) for the Ageing Society' (2016-2017), Scientific Supervisor Professor E. Arbizzani ('Sapienza' University of Rome), Operational supervisors P. Clerici Maestosi (senior researcher, Enea) and P. Civiero (RTDB researcher, University 'Roma Tre'); 2) 'Smart Housing Design per l'utenza fragile – Nuove forme abitative e tecnologie a supporto della qualità della vita attiva degli anziani' (2019-ongoing), Scientific Supervisor Professor L. Reale ('Sapienza' University of Rome); 3) 'Senior Housing and Smart Technologies for the Elderly – Modelli tipologici e servizi digitali per il progetto e la gestione delle residenze per anziani' (2020-ongoing), Scientific Supervisor Professor E. Arbizzani ('Sapienza' University of Rome).

9) The data import process in the database was supported by the Revit DB-link® app which, through the link with external databases and servers, allows to continuously update the informational content of the project.

10) ISO 16739-1:2020 – Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries.

11) The informative model is organised according to the guidelines of the UNI 11337-1:2017 standard and is based on an open and interoperable format, following the international ISO/TS 12911:2012 and ISO 16739-1:2020 standards.

12) To process data for the assessments on the energy-environmental and visual-lighting comfort the interoperability with some softwares capable of communicating with the IFC standard was considered: Autodesk Ecotect®, Energy Plus®, Dialux®, as well as the Mantus Acca Software® for maintenance activities. This stage is under verification and implementation.

13) For example, reference is made to the COBie format capable of handling all the digital facilities (e.g. no. of people in the room, staff assigned to perform specific activities, presence of users, reading of device parameters, etc.)

14) ISO 19650-1 Common Data Environment, 'Agreed source of information for any given project or asset, for collecting, managing and disseminating each information container through a managed process'.

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ENVIRONMENTAL DESIGN
Nature and pathways connecting Cadorna Station and Triennale Milano

Davide Bruno, Felice D'Alessandro

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Abstract
This article investigates the Master Plan measures for the environmental, cultural, and social regeneration of a highly historical and monument-dense area of Milan, by the European guidelines against climate and environment-related issues, in the framework of a competitive and efficient economy in terms of natural resources. We present several approaches to foster a dialogue on the cross-discipline character of climate-adaptive design in urban contexts as a research ground for the development of strategies and innovative solutions, as well as new cultural models to support the green transformation of anthropized environments.

Keywords
environmental sustainability, green infrastructures, design of cultural eco-systemic services, inclusion, nature, and art

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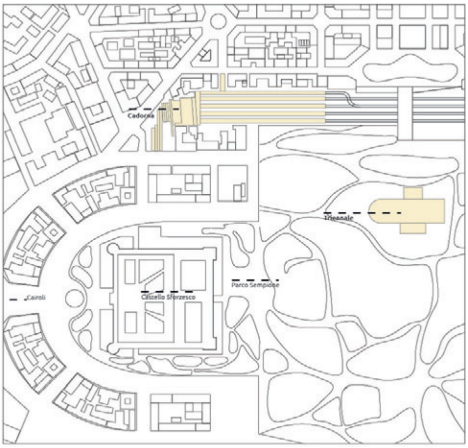
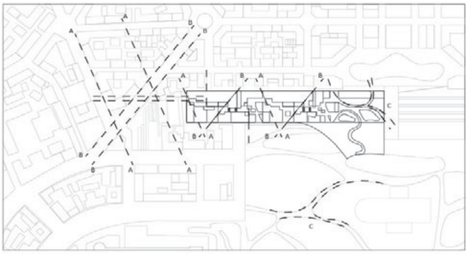
The definition of 'green design' first appeared in the book Small is Beautiful by Ernst Friedrich Schumacher (1973), a German economist, philosopher, and writer who challenged the modern Western paradigm that focuses on consumption, big industry, and organizational centralism. Schumacher anticipates some ecological themes that will lead to success in the following decades. Humanity is consuming nature's capital at an alarming rate without considering that resources are not infinite. This leads to a materialistic economy based on the individual pursuit of maximum wealth, which, not knowing the principle of finiteness, is not suitable for a limited environment. According to (Calvino, 1973, p. 42), we could be approaching a time of crisis in urban life, and the Invisible Cities are a dream sprung from the heart of unliveable cities; today, we insist both on the diffusion of the natural environment, and on how frail our great technological systems are, thus capable of triggering cascade failures which can paralyze entire metropolises: the crisis of too large cities is the other side of the crisis of nature[1]. The study described in this article is motivated by the desire to create and experiment with new project solutions to integrate the natural environment with built-up spaces.

Cities are the most suitable places to challenge the adaptability of urban systems to climate change (Kane and Shogren, 2000): if on one hand, the urban systems produce negative, climate-changing externalities, on the other hand, they are a privileged context to innovate and experiment with mitigation practices, that can adapt to the self-provoked impact (Musco and Patassini, 2012). The urban environment is hence a singular scenario, through which we can watch and analyse the needs and desires of contemporary society. In recent times, the design of public spaces and infrastructures has been focusing on the integration between natural processes and urban environments, promoting a kind of regeneration based on the activation of new social and environmental functions that are typical of cities (Perrone and Russo, 2019).

Within this cultural framework, and analysing the contents of the Master Plan[2] (MP) of Cadorna's area in Milan, this article recalls some of the design strategies aimed at regenerating the urban tissue, to establish new guidelines to find a balance between conservation and today's need for resilience, sustainability, transformation, and use of public spaces (UN General Assembly, 2015, 2017; Rockefeller Foundation, 2015), according to principles of multi-functionality, connectivity, and transcalarity (European Commission, 2013).

The present article, while attempting a 'biophilic' approach to design (Marshall and Williams, 2019), offers a contemporary point of view over the idea of green as a multi-functional, strategic element to the reactivation of resilient processes in heavily built contexts (Forman, 2014). Ecologically efficient green areas play a fundamental role in carrying out performative eco-systemic functions (Rigillo, 2016), opening new research scenarios. Here, a need for pursuing a dynamic balance among different environmental factors, eco-systemic capability and changed social needs emerges. Adaptive urban design is an opportunity to think about the relation between artefacts and nature, as well as about our ability to embrace change rather than oppose it, and to cre-





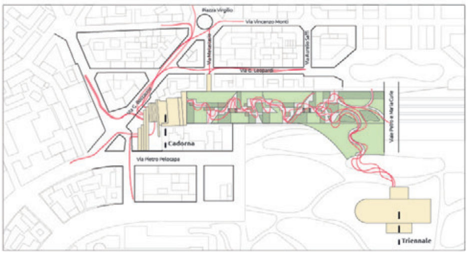


Fig. 1 | The intervention area (credit: D. Bruno, 2016).

Figg. 2-5 | Intervention area and flow analysis (credits: D. Bruno, 2016).

ate new opportunities from instability and crisis. The ideas of adaptability, transformability, and reactivity can be interpreted as new requisites which, in terms of adaptive capability, can integrate the ecological efficiency needs of the human habitat (Angelucci, Di Sivo and Ladiana, 2013).

Specifically, this article is divided into six sections. The first one introduces the motives of the project and the genesis of its idea, consistently with European and international reference models. The second section describes the methodological and operational approach. Special emphasis is given to the development of green infrastructures and environmental benefits, as explained in the third section. Before proceeding to the fifth section which describes the obstacles and constraints of the project and its dissemination as a good practice, in the fourth section, we will focus on the need to re-establish relations with nature and art within the urban context, valuing continuity in a contemporary culture of design. Based on the analysis of selected international case studies, the sixth section focuses on the verification of the project idea. The article ends with conclusions and future visions.

The contents call for a reflection on the potential of synergic design, highlighting a need to reinforce the cross-discipline character among scientific research, environment, economy, and society aimed at a sustainable and futuristic design of future cities.

Reasons behind the project: an integrated approach to European and international models | The railway stations are going through an identity crisis. They are 'non-places' plunged in often pleasant and sometimes spectacular landscapes (Augé, 1992). They need to flawlessly blend in, pairing the beauty of shapes, functionality, usability, and circular sustainability of their operation. While cities still struggle with the recovery of their identities, 'non-places' in their landscapes can transform and shape their communities, experimenting with the creation of new celebrity and reputation on the territory. Stations evolve and become more competitive, and offer their users unprecedented services as well as miscellaneous opportunities. Space planning makes them welcoming, the most diverse offer permeates every corner and meets a society that lacks time. In line with the existing city challenges, the station shall be key to urban reorganization, and representative of sustainable mobility. Having a leading role in the new set-up of the urban tissue, it becomes an interchange centre with an economical-cultural value. Here, we intend to limit the impact of railway lines on urban areas, turning them into assets. Train tracks shift their role from barrier to connecting elements.

From our analysis, the role of stations in the cities of the future will be threefold: fulcra of mobility, event laboratories, and places for physical, intellectual, and cultural recharge. Every renovated reality will allow the city to reshape and create new poles, hindering its limits. Cities are resilient, capable of evolving without expanding by optimizing the existing, abandoned, high-potential areas. From this perspective, the railway context turns into a development model that encourages the urban review of the rest of the city. The railway context longs for becoming a new centre, a modern version of Agorà. The railway buildings are actual monuments, strongly rooted in the places they connect, establishing a symbiotic relationship with the city. Their central position projects the travellers into the city: the building lessens the bewilderment

caused by a fast change of location, which causes a lost perception of the surroundings (Giardiello, 2011). Therefore, railway buildings are a joint between separate worlds and become places to redefine functions, structures, strategies, and new poles.

The MP of Cadorna's area is part of the European plan for integration (European Commission, 2011), among collective transportation leading lines, and infrastructures (local railway stations), for the creation of a new way to avail of 'non-places' at a regional level. The framework of the MP is wide: from theoretical research and analysis of international case studies to on-the-field practice (through co-design and involvement of local stakeholders in the project choices), to reach citizenship in a strive for participation and social inclusion.

The specific challenge consists in transforming the railway station of Milano Cadorna, consistently with the sensitivity and generative capacity of the place, into an immersive, highly communicative space, strongly characterized by new digital and/or traditional forms capable of conveying to viewers: a balanced level of mediatic information (against semiotic abuse); new ways to praise the territory (emphasizing landscape and beauty of the local area); recovery of the central role of new forms of contemporary art. At the basis of the project is the idea to offer the onlookers a two-speed system. On one hand, a station at full throttle, characterized by the typical dynamism of high-quality industrial artefacts, precision, and transparency in the daily movements of its inner workings; on the other hand, a slow, monolithic station, that conveys the idea of a docked ship, ready for sailing.

It also defines a new abacus as arbitration between past and present, introducing new functions, materials, and shapes to connect the central part of the square to the

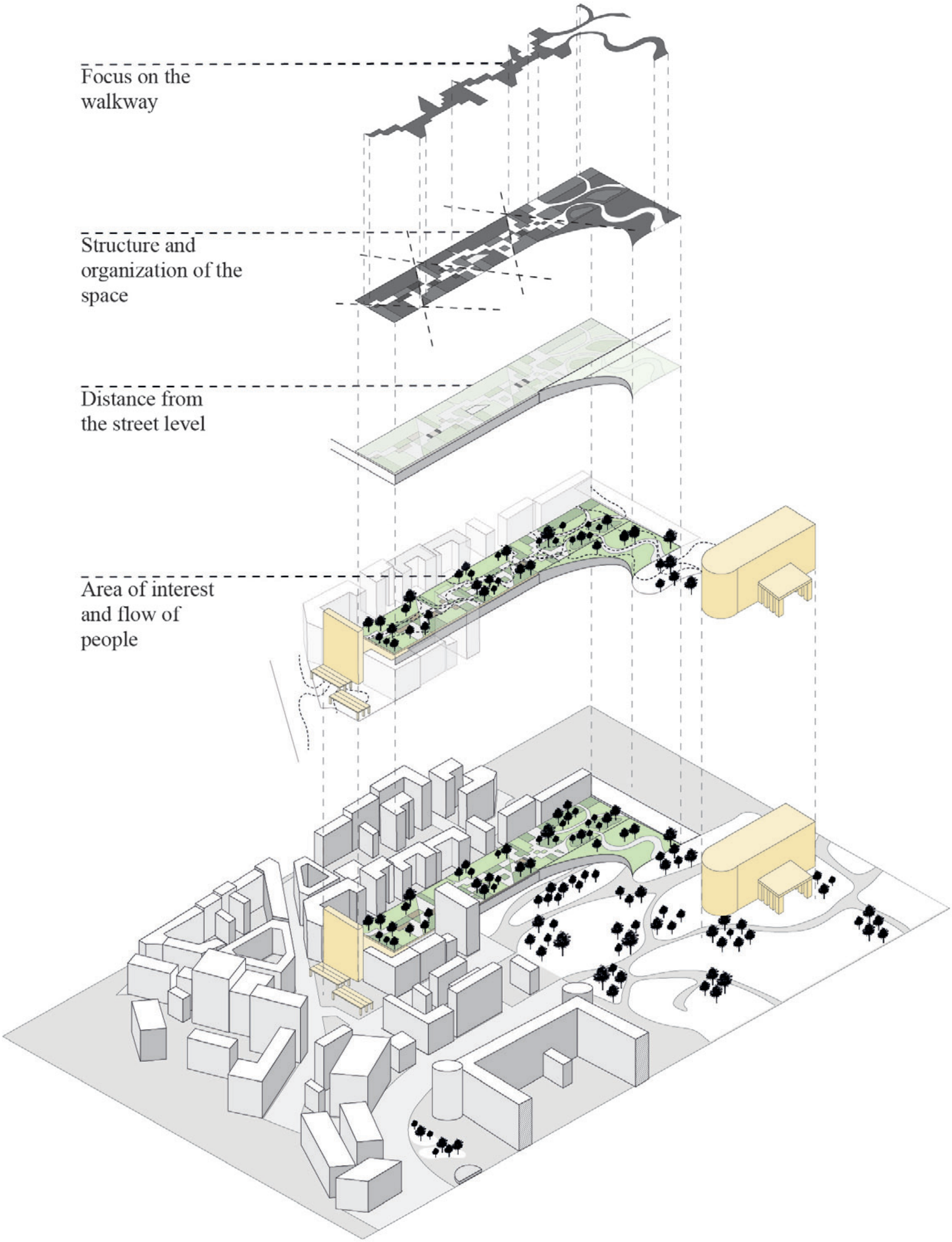


Fig. 8 | Main layers of the new natural and built-up environment, in relation to the status quo (credit: D. Bruno, 2016).

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Fig. 6 | Perspective and section drawings of the buildings, the new canopy, and the underground rail system (credit: D. Bruno, 2016).

Fig. 7 | Internal view of the new canopy (credit: D. Bruno, 2016).

Triennale park, thus reconciling two areas of the city with the creation of a joint, a shelter, a great hydroponic green river supported by a light tensile structure, characterized by grass-covered areas and immersive paths of works of art, installations, and technologies (Figg. 1-5). To observe the constraints given by the flow between inner and outer areas, we decided to develop an overhead itinerary, in the open air, recreating a connection between parts of the city, as an example of a highly porous, open system, linked to the Triennale gardens (Fig. 6).

The canopy is conceived as an effective and formally expressive tool to cover the railway tracks (Fig. 7), and joins the existing urban context like a fluid element, an object whose unity and direction towards Triennale look always different (Fig. 8). The station appears as a docked ship. Six sails on the canopy accentuate this impression, conveying the typical sense of fluidity that belongs to the gentle rocking movement of the waves. The architecture is entirely dominated by the movement of the station and the travellers; the space between the sails is conceived as a natural connection among the services inside the building, staggered by the architecture itself. This natural continuity among different spaces, the context-inclusive architecture, and the material choice which links and unifies all the elements within the volume, conveys an idea of organicity.

The strong presence of green meets the European guidelines for greening politics. The process of reunion of two city areas is carried out through the creation of an overhead, 380 meters long canopy-bridge which joins, with a nearly 32,000 square meters area, via Leopardi and the Triennale park, over railway tracks and secondary streets. The infrastructure shapes the bed of a hydroponic green river, which structures immersive paths of design and technology installations. More specifically, the idea of a cultural eco-systemic path from Cadorna station to Triennale Milano aims at strengthening the link between the natural environment and built-up area, in a new symbiosis. In one of the most suggestive, historic, and monumental contexts of Milano, this vertical garden, animated by a maze of green paths, will act as an imaginary factory producing oxygen for the city. The collection and re-use of rainwater would also offer better water resources management and the mitigation of extreme pluviometric effects in a circular vision of the natural processes, aimed at improving the environmental as well as the socio-economic conditions.

In the heart of the city, architecture turns a station as a 'non-place' into a dynamic, moving structure, and finally gets rid of the fracture of the ancient urban design in a new, highly permeable system in connection with the Triennale gardens, entering the forest of surrounding buildings as a fluid element (Carta, 2013). The greening intervention is hence the chosen tool which turns the Plan's guidelines into factual action, in a historic context where the physical transformation of spaces is often extremely difficult (Boeri et alii, 2017; Dessì et alii, 2017). A pioneer and visionary project that has the re-establishment of a connection between the city and natural environment as its goal, through the creation of high-quality and highly liveable public spaces, in line with the accessibility represented by the Milano Cadorna Station in its new inclination to meet the needs of travelling citizens. The project hence pairs natural elements and artefacts, biological cycles and building processes, tradition, and innovation determining the high quality of its new set of technological, eco-systemic, and efficient offers, enriched by artistic and cultural suggestions (Figg. 9-11).

Even though the scope of the MP is well-defined and localized in the Milanese context, a multi-disciplinary approach, in-depth study of the state-of-the-art, as well as evidence-based design, create an underlayer of knowledge that can be transferred into different contexts, both at a national and at an international level.

A new methodological and operative approach | The original character of the contribution can be inferred from the double approach, methodological as well as operative. The methodological aspect is based on the research of balance in the scenario of a 'non-place', between the request for conservation and the new need for resilience, sustainability, transformation, and use of the collective spaces, where an integrated reading of the existing situation creates value through a project layer that systemizes overlapping layers of urban stratigraphy (railway tracks/canopy/green river). To address our research question, this study has explored knowledge, projects, and experimentation, 'contaminated' by the European context. In particular, the pedestrian Promenade Plantée in Paris, also known as Coulée verte René-Dumont (Fig. 12), the High Line in New York (Fig. 13), the overhead garden of Sants in Barcelona (De Francesco, 2017; Fig. 14) have been selected as reference cases.

The selected case studies present significant projects for reinterpreting the urban tissue, aiming at establishing a connection between the built environment and the network of environmental and social processes in the cities. From the analysis, shared methodologies and design objectives, leading to the experimentation of innovative solutions have been found. Firstly, the exploratory analysis considered the technical solutions adopted by the greening systems to promote the refunctionalisation of the grey infrastructure, the creation of benefits from the point of view of the psycho-physical and social well-being of the local community and the sustainable integration between building and environment.

A second, equally innovative aspect is laid out in the 'operative' dimension. From a visionary illustration of the contribution, we can outline in detail the design elements that contaminate the scenario in the eyes of the onlookers. The project opens to an array of industrial, artistic, and technological products which clearly define a historical, contemporary, and projected path through a careful, continuous design process that spans over time, from the proto-design of the great masters to new generation materials; from creation matter to the cultural inversion leading to a green sustainable process. The original contribution can be seen in the right match between cultural, green, technological, and design elements which outline a multi-disciplinary approach, aiming to suggest a best practice as a tool for prefiguration and a reference model that is adjustable to different urban contexts.

Modular walkway with geometric shapes, composed by several elements of urban furniture

Enhancement of the greenery, with separate areas for different species of vegetation

The public space is distributed on several floors and offers shady areas thanks to the presence of many hanging gardens

The area offers green spaces for conviviality thanks to the presence of many seats

Zone of connection with Sempione Park. With its organic shape and large spaces it can house the most iconic works of art

Perspectives for the development of green infrastructures and environmental benefits | In Europe and the world, a social and economic process determining the gradual abandonment of rural hill and mountain areas is taking place, together with the intensification, in terms of occupied surface and residential density, of the urban systems. The effects of climate change (heat islands, intense precipitations, floods) add to this already critical situation, and the urban areas can be considered as both generators of hazardous conditions and exposed goods. The critical environmental issues that our cities are facing require a re-thinking of the analytical and design approach to habitat transformation, which contributes to the alteration of the eco-systemic balance related to wellbeing, health, and access to resources.

We are witnessing a change of paradigm in the transition from sustainability culture to resilience culture. While thinking in terms of perfect balance among social equity, economic possibilities, and environmental constraints is no longer enough, resiliency comes to suggest a dynamic balance in the terms of sustainability, which should include continuous changes of status and a new start after a critical phase. These cyclically mark the interaction between humans and the environment (Dell'Acqua, 2020). The mandatory character of the environmental issues, together with the acquisition of a paradigm of resiliency within the project culture, has determined a remarkable development of the disciplinary debate, shifting the attention of the scientific community from research objectives that were mainly oriented to the conservation of resources (safekeeping of the natural capital through sustainable use of them), to more focused studies around the nature of anthropized systems and the advantages of their re-design from an ecological point of view (Rigillo, 2016).

The urban project becomes the place for transcalarity and multi-objective, promoting strategies where the green systems correspond with a vital re-interpretation of stratified (urban) landscapes. Taking inspiration from the Lynchian metaphor of cities as 'learning ecology' (Lynch, 1981), we can nourish the design activity originating research activities around the ecological function of urban spaces focused on the interaction between natural cycles and the peculiarities of built-up environments (pattern, materials, technologies, building processes (Niemela et alii, 2010). Through this approach, we can re-define the relationship between the built-up environment and nature: a 'gentle' invasion of green into the urban tissue (Zaffi and D'Ostuni, 2020) which mimics the natural colonization processes that are generally hindered by humans (Fig. 15). In this context, urban green areas play a fundamental role in the implementation of projects aimed at limiting the cities' vulnerability.

The increased awareness of the role played by natural resources in the creation of urban resiliency guides policies and actions aimed at a reconfiguration of spaces, following an adaptive approach that acknowledges the value of green infrastructures and

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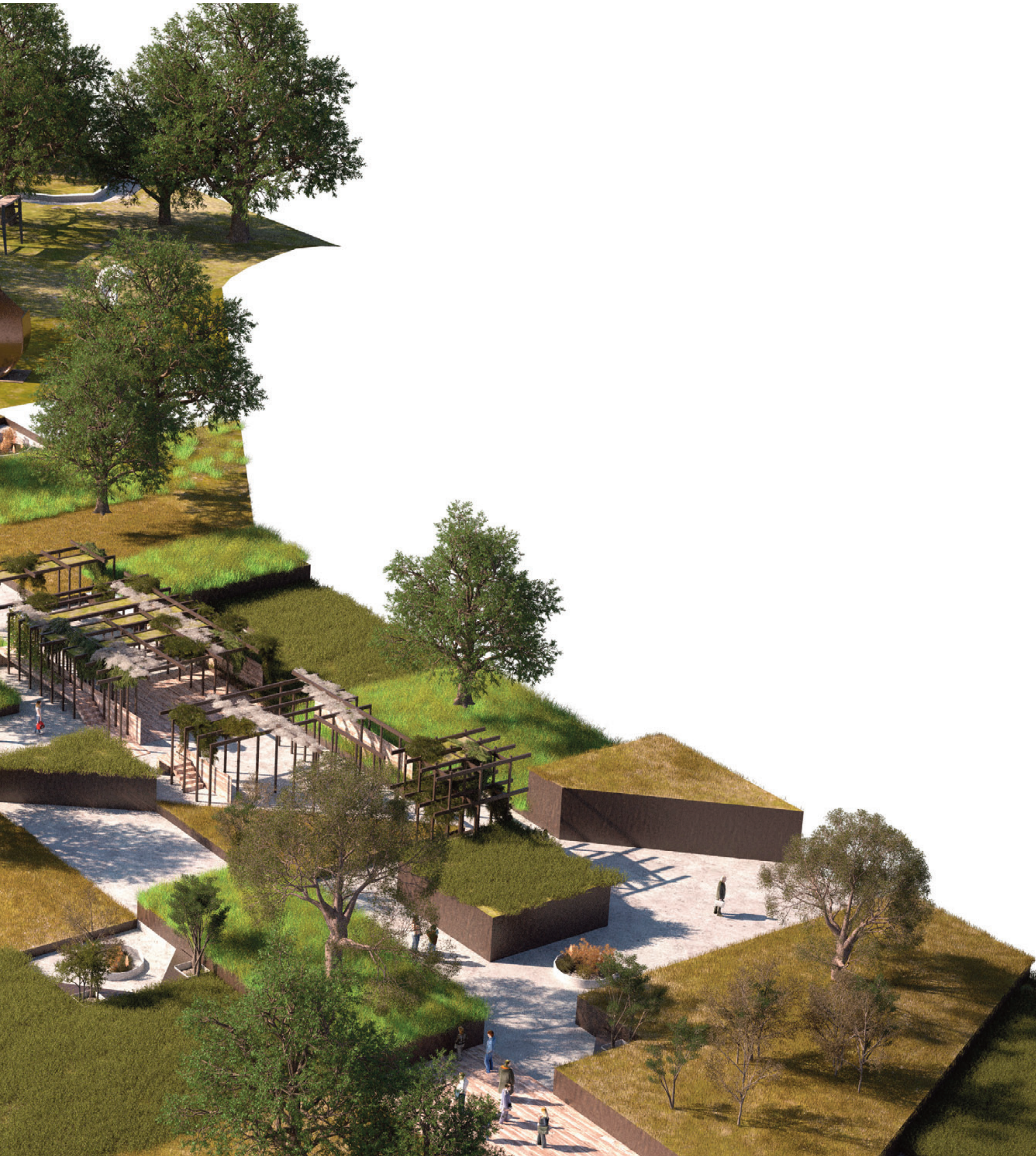
Fig. 9 | Union between the natural environment and sustainable artificial elements (credit: D. Bruno, 2016).

Fig. 10 | Design and art elements on a hyper-scale (credit: D. Bruno, 2016).



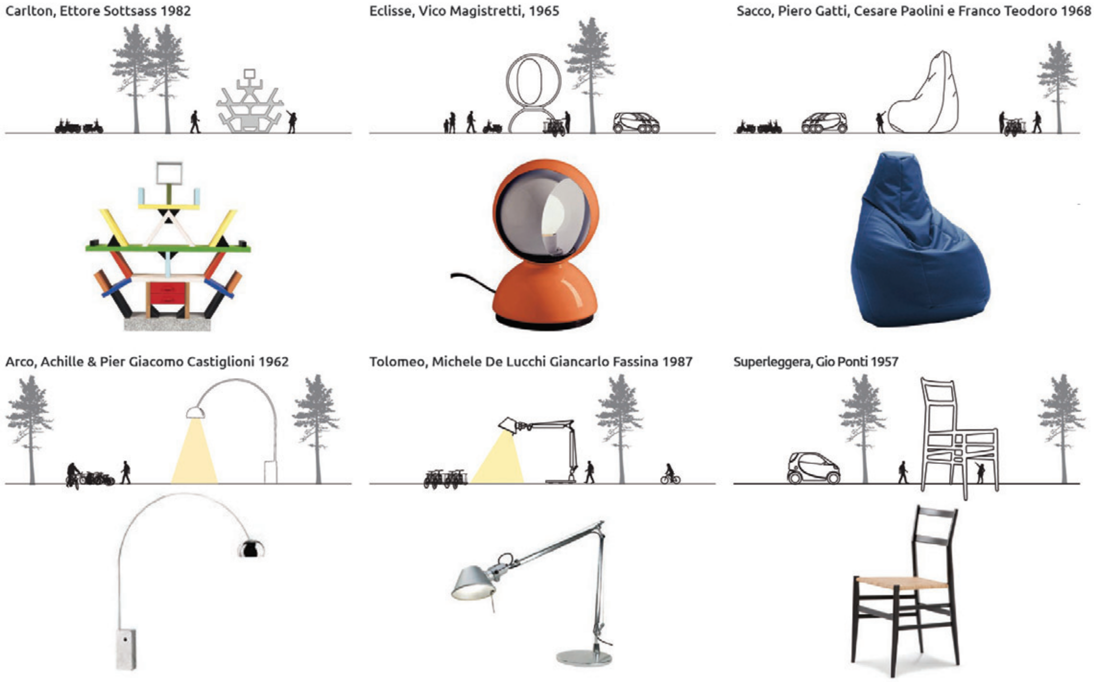


Fig. 11 | Selection from a taxonomic element of design objects on an urban scale (credit: D. Bruno, 2016).

eco-systemic functions. In the framework of these needs, we can find the theme of green infrastructures at different levels of integration of nature in cities. They are recognized to contribute to the environmental quality of anthropized systems and, more specifically, to lower vulnerability in terms of climate change (Dell'Acqua, 2020). Adopted in several disciplinary fields and widely used in design and planning, the expression green infrastructure has more than one meaning. Mainly represented by two different cultural and geographical matrixes – from the United States and Europe – we can find references in authors such as Benedict and McMahon (2002), who in the beginning of the years 2000 in the United States linked the idea of green infrastructure to that of an interconnected network of natural areas and other open spaces, maintain natural ecosystem values and functions, sustain water and air quality, and provide a wide range of benefits to people.

Both in the description of the green infrastructure and their ascribed functions, the definition by Benedict and McMahon recalls the idea of the ecological net as found in literature, projecting it into a sustainable planning logic that considers natural areas as an essential resource for human wellbeing. The 'infrastructural' value of the natural capital is hence acknowledged in its Anglo-Saxon meaning of common good, used to support the idea of an active safeguard of resources. As opposed to that, the European approach highlights the multi-function value of green areas and recognizes the fundamental role of green structures in the contribution to sustainable urban development (Sandström, 2002). At the core of the idea of green infrastructure is the understanding of the advantages related to inter-connectivity, and the conception of them as more than a simple sum of different parts. The latter generates indeed fewer benefits than the potential expressed by their synergy. So, the idea of green infrastructure qualifies for its characteristics of multi-functionality, inter-relation, systemic nature, and provision of differentiated services (Dell'Acqua, 2020).

Among the main pursuable objectives in the design of green infrastructures, the ones linked to the management of water resources – also through the implementation of hydroponic cultures – and to the recreational functions emerge, taking on a strategic role in the climatic adaptation of cities through eco-systemic services and ecological, economic, and social benefits that such nature-based solutions are capable of providing. However, new variations to green infrastructures emerge after the remarkable changes in our reality. After the recent happenings, the academic world has started to show an increased interest in the implication of the human-nature relation on people's wellbeing, contributing to a more in-depth analysis of its consequences from a social and relational point of view (Perez-Urrestarazu et alii, 2021; Dobson et alii, 2021).

It is on these premises that the green infrastructures adopted within the scope of the MP shall become functional to an adaptation in its broadest meaning, from the need to re-establish a relationship with nature and art to increasing the inclusion of intangible components – digital networks to support the maintenance and care of the natural capital in the urban context (with IoT and Artificial Intelligence technologies) – and to turning the open space before the station from a 'non-place' to a potentially safe place to recover new normality (Scalisi and Ness, 2022).

Elements of human-nature-art relation | There are multiple images as well as reading and representation paths for the relationship between humans and nature. Literature, philosophy, and art have shaped this relation, depicting in history their harmony and contradictions. One of the goals of the MP is to highlight the vegetable element in its social implications. Can Nature, in symbiosis with art, witness and take part in human history, and operate towards a change? And if so, how? The project aims at opening a space for reflecting on the human-nature-art relation, fostering awareness on the ethical dimension as well as on a mutual faith which unites nature and humans, in opposition to the idea of unlimited resources, hence relieving the frailty of the ecological environment. This frailty makes it essential and urgent to commit to safekeeping and conservation, together with the education to mindfulness and sensitivity within ethics of responsibility. The green itinerary that looks towards the Triennale park is not only an open-air museum but a relational space between art and life, a match of nature and artefacts. In using nature as an

Fig. 12 | Promenade Plantée, Paris (credit: J.-L. Zimmermann, 2009).

Fig. 13 | High Line, New York (credit: Iwan Baan, 2008).

Fig. 14 | Raised garden of Sants, Barcelona (credit: A. Goula, 2016).

aesthetic element, art plays an active role, animating the scene with highly symbolic works and objects, mixing tradition and avant-garde of the Italian design, and anticipating future artistic revelations.

Constraints and obstacles of the project | The limits of the project lie mainly in the articulation of cross-cutting competencies at various levels, concerning both the design phase and the execution phase the intersection of structural engineering and management engineering with the aspects of civil architecture, interior design, the design of the object population and an 'open-air museum system' that is supposed to mend and connect two urban tissues like a hinge. Therefore, the complex set of all these activities that need to be linked together, in the absence of a highly qualified direction oriented towards a multidisciplinary approach, could be a real and extremely limiting constraint to the success of the project.

In addition, problems of a political and economic nature, easily encountered in environmental and territorial contexts comparable to those of this case study, should be considered as potential obstacles to the implementation of the project. A third aspect concerns the layering and sedimentation of a new project in the existing reality. In the execution phase, it will therefore prove necessary to create a development model that can guarantee the operation of the station without limiting the quality and efficiency of the services offered.

Verification based on case studies | Operational reality is generally characterized by a variety of factors and conditions, some of which elude the arguments presented above. Therefore, it seems appropriate to verify some of the discussed issues by means of practical project opportunities that provide synthetic readings of the transformability of places through comparisons. In particular, two case studies have been analysed (High Line in New York and Promenade Planteè in Paris) from which we have tried to extract symbolic aspects, structural elements, and perceptual modalities as indicators that characterize the project. The two analysed case studies make it possible to explain the indicators in a differentiated way by showing the predominance of some aspects over others or the absence of some factors, thus allowing a comparison of the different evaluation outcomes. By comparing the case studies with the Milan project, we can generally observe that the transformation of the railway infrastructure, as a kind of intervention in the city, becomes part of the totality of public spaces in different ways.

Specifically, the case of New York's High Line proposes the least transformative project of the infrastructure's characters, focusing on the architectural qualities of the building. The symbolic factors that give the viaduct the significance of an urban monument have been decisive in this design. Therefore, the more specific attributes of the

Fig. 15 | Bird's eye view of the new intervention (credit: D. Bruno, 2016).

Fig. 16 | Integrated simulation of the new intervention in relation to the buildings and urban context (credit: D. Bruno, 2019).

infrastructure, such as the structural section and the perception along the railway line, take on greater importance. The case study of the Promenade Planteè in Paris presents a less radical alternative than the previous one. It has succeeded in selecting some features of railway architecture that can be integrated into the cityscape and focusing the project on solving peripheral areas. In Paris, it is mainly the considerations of perception that play a role, both in the design of the elevated railway and in the transformation of the 'parts' of the infrastructure into urban artefacts (the long building, the pedestrian bridge, the large path, etc.). However, some structural aspects are also of considerable importance, such as the relationship of the forms influenced by the different positions of the path, which determine the dimensions and the specific character of each segment of the path.

In the case of Milan, the project idea, aimed at the environmental, cultural, and social revitalization of a highly historical and monument-dense urban area, has allowed the symbolic factors, the structural elements, and the perceptual sensations to coexist to strengthen the link between the natural environment and the built space. In particular, the morphological features of the settlements significantly impacted the definition of the design strategies, which also influenced the relationships and the perceptual qualities of the intervention. By declaring nature as an aesthetic element, art plays a proactive role, enlivening the scene with highly symbolic works and objects and introducing a population of industrial, artistic, and technological products that mark a historical path through the mix of tradition and avant-garde of Italian design.

Conclusions and future visions | This article describes the outcome of a project that aims at identifying a new eco-systemic and cultural path from Cadorna station to Triennale Milano, devoted to an environmental and social recovery of a strategic area of the city, that is also dense in history and monuments (Fig. 16). The project suggests the addition of a new design 'level' as a tool to recover the historical reasons (artistic and monumental patrimony) integrating them with the contemporary needs (sustainability, wellbeing, inclusion), with the purpose of bringing the project to the centre of an effective cultural development process. In an up-cycling approach, the original function will be integrated with new creative uses, that are closer to the citizens' needs and more impactful on the economic and social dynamics of a contemporary city (Ferlenga, Biraghi and Albrecht, 2012). The possible applications of the Plan and the related synergies have the potential for being fruitful pilot-projects, encouraging the creation of new initiatives and projects for the adaptation of built-up environments to the effects of climate change. At the same time, they shall promote mitigation solutions in green regeneration-inclined contexts. The adoption of green infrastructures with water-saving/reuse systems, together with the use and/or supply of renewable energy with the support of digital solutions, become necessary in an urban circularity approach (Carli and Scrugli, 2021).

A second element for positive reflection comes from the collaboration between universities and institutions to receive multi-disciplinary contributions, and to translate research and experimentation into opportunities, also fostering the scientific debate within a vision that is inclined to support the development of solutions for urban resiliency, in a process of ecological transition.

Although this article presents a qualitative reflection on the possibilities of green infrastructures, we need to carry out a quantitative analysis to depict a more comprehensive scenario of their strengths and weaknesses. The implementation of nature-based solutions with high technological content would allow for: 1) investigating the technical aspects of plants as design material, in terms of performance, durability, and maintenance; 2) identifying vegetable species that better respond to the need for shade and evapotranspiration, according with the site climatic characteristics. In a broader vision, an analysis including quantitative data might contribute to improved environmental, economic, and social sustainability through the development of structural elements that are linked to the territory. The outcomes of this project do not intend to diminish the cross-disciplinary complexity of the subject, to complete the amount of available information, or to define a unique process. Future studies on the relation among these aspects could highlight new disciplinary alliances or methodological guidelines to interpret the need for a virtuous bond between the natural environment and built-up space.

Acknowledgements

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Notes

1) In the lecture Italo Calvino gave in English to the students of the Graduate Writing Division of Columbia University in New York on 29 March 1983, he gives us a compass with which to orient ourselves in his work, with basic indications of its genesis, content, and its particular structure.

2) The Master Plan for the Cadorna – Triennale Milano area has been prepared as part of the agreement between La Triennale Milano Foundation, FERROVIENORD S.p.A., and the Municipality of Milan to ensure better permeability between the Cadorna station, Parco Sempione and the Triennale. Prof. Davide Bruno of the Politecnico di Milano coordinated the scientific activity of a multidisciplinary research team involved in the development of the Master Plan.

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COMMUNICATION DESIGN FOR HEALTH
Territorial and digital networks

Daniela Anna Calabi, Alice Maturo, Marco Quaggiotto

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Design

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Research & Experimentation

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Abstract
In the wake of the Covid-19 pandemic emergency, there has been renewed interest in issues related to health, prevention and community well-being. Health communication and the promotion of disease prevention now require a theoretical and design approach that first and foremost requires the identification of appropriate tools to enhance 'intersectorality', 'collaboration' and 'outreach' among the different areas of expertise of the well-being and healthcare actors involved in the territory. The aim is to strengthen the process of community 'empowerment'. This study investigates the communicative strategies suitable for enhancing the physical, virtual and digital relationships among the active presences in the territory, choosing those capable of mediating needs, promoting well-being and building a dialogue between citizens and health facilities, thus finally creating a 'territorial health network'.

Keywords
territorial network, health and wellness, mediation, communication design, community empowerment

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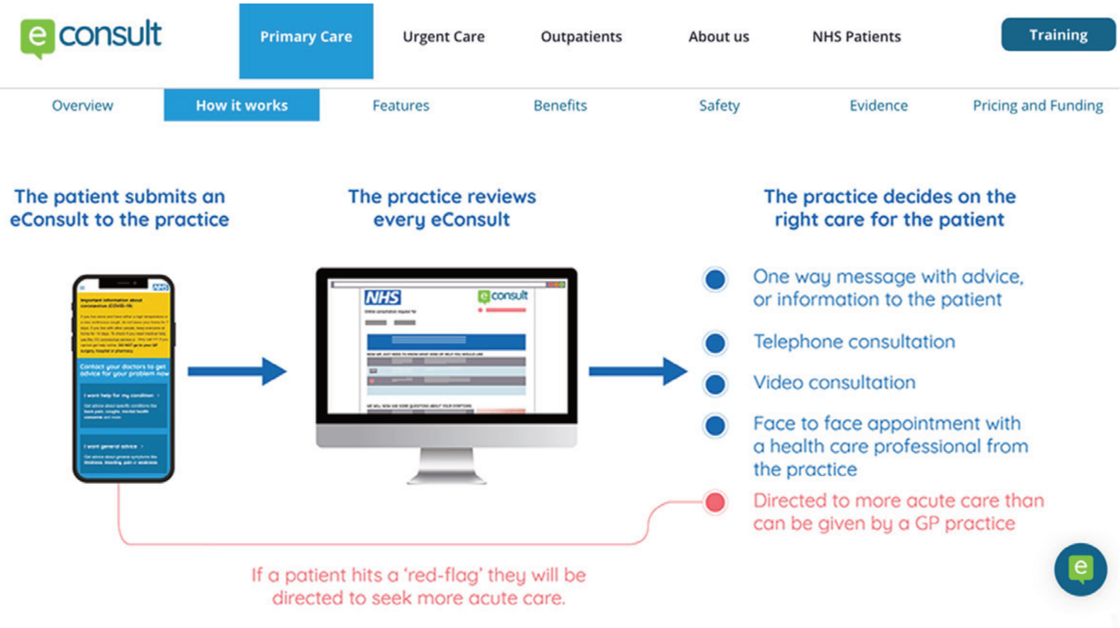
Health, disease prevention and community well-being are the core principles of the Polisocial Award 2020 initiative of the Politecnico di Milano: ‘Vulnerabilità e Innovazione nell’era post Covid19’ (Vulnerability and Innovation in the Post-Covid19 Era), which among the winning projects saw ‘Coltivare_Salute.com – Città e Case della Salute per Comunità Resilienti – Le Case della Salute quali costruttori di urbanità e socialità diffusa nell’era post Covid-19 – Nuove centralità periferiche in città salubri e integrate’ (lit. Cities and Health Homes for Resilient Communities – Health Homes as builders of urbanity and widespread sociality in the post Covid-19 era – New peripheral centralities in healthy and integrated cities).

This project involved an interdisciplinary research group, composed of four Departments of the Politecnico (DASTU – Department of Architecture and Urban Studies, proponent; DABC – Department of Architecture, Built Environment and Construction Engineering; DIG – Department of Management, Economics and Industrial Engineering; Department of Design), in collaboration with external partners from the health districts of the city of Piacenza (Local Health Authority USL, Municipality, Associations, Emilia-Romagna Region, Territorial Committees). The main objective, which the working group focused on within the project, was the study of an operational methodology which could be replicated on national territory. Project guidelines were defined in order to enhance the impact of the Case della Salute[1] (CdS) on the territory of the Italian Emilia-Romagna Region, useful for restoring the role of health centres to the CdS, also in view of the recent pandemic situation. The desired transformation envisages the transition of the CdS from multi-purpose facilities, of a purely health-related nature, to places of health efficiency, but also points of reference for social regeneration, architectural redevelopment and urban structure.

The World Health Organisation (WHO, 2021) defines the concept of health as «A state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity». This definition has paved the way for multidisciplinary approaches and the expansion of research areas, including Communication Design. Peter H. Jones (2013, p. viii), while on the subject of Design for Care, reflects on the convergences of approach between Design and Medicine: «These two fields are similar in many ways. Both are conducted as skilled practice informed by experts who learn by doing. Both are informed by observation and feedback, by evidence of their beneficial effects. Both disciplines are motivated by a deep desire to help people manage and improve their lives, individually and culturally». In particular, it is assumed that Communication Design, by its very vocation, acts as a bridge that fosters relationships between different subjects, mediating and implementing communications.

The research that follows is located within the Polisocial project and refers specifically to the results related to Communication Design applications. The communication project defines a greater involvement of the community of citizens starting from the understanding of the definitions of ‘well-being’ and ‘health’ as ‘relational’ concepts, as they depend on the continuous exchange between individuals and are determined



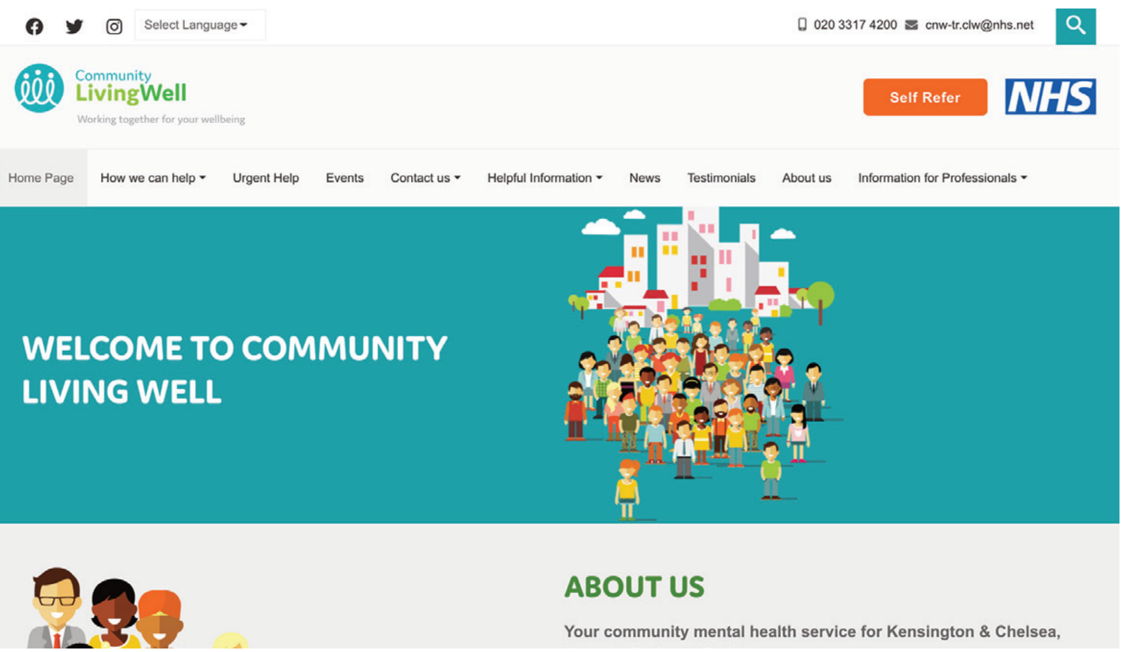


Fig. 1 | eConsult (2016), by National Health System Self-Help, UK (source: econsult.net).

Fig. 2 | Community Living Well, West London Clinical Commissioning Group, designed by C27 Media, UK (source: communitylivingwell.co.uk).

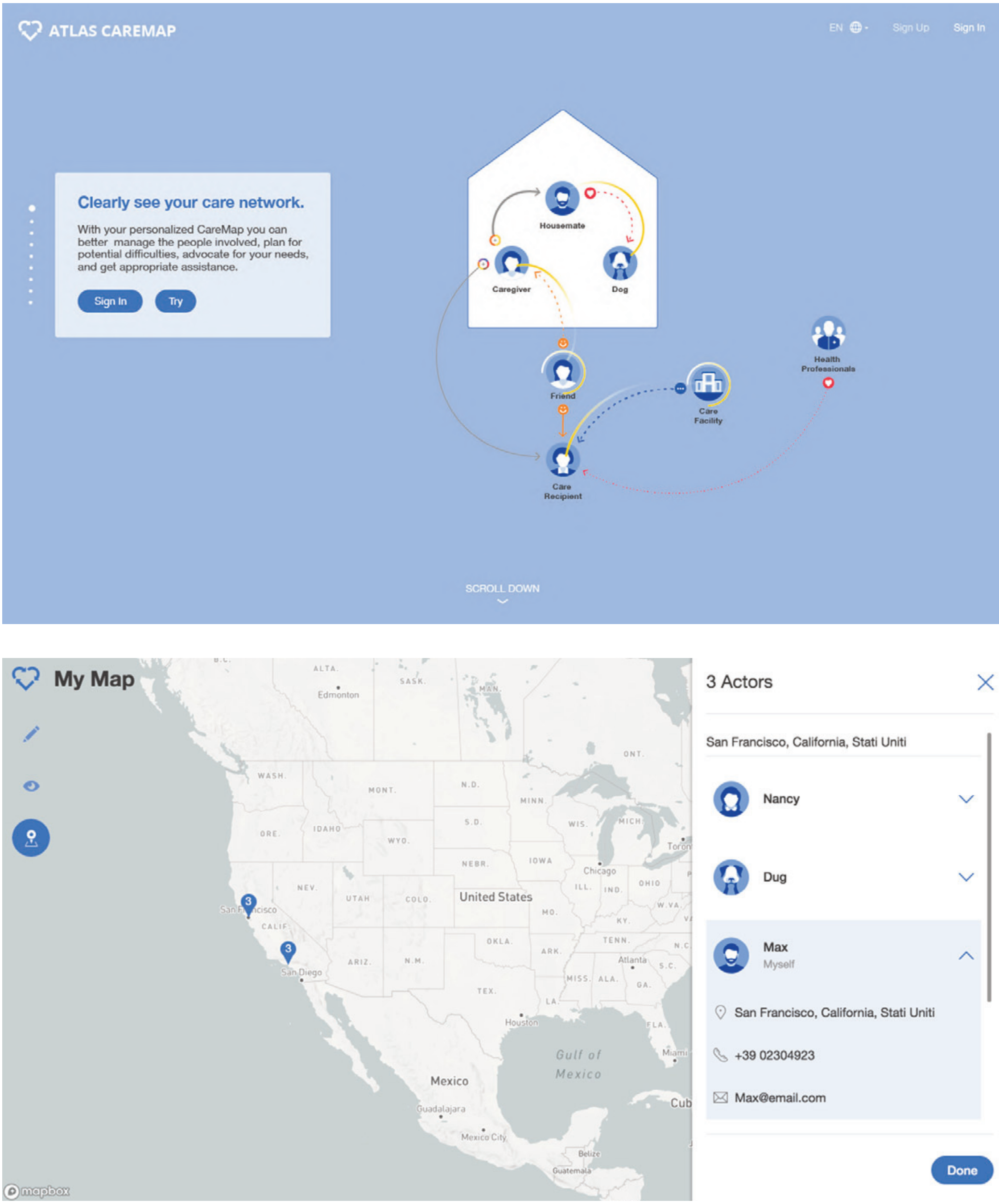
Fig. 3 | Parma Salute, Comune di Parma, Italy (source: comune.parma.it).

Fig. 4 | Mappa della Salute #bastapoco (2017), Regione Emilia-Romagna, Italy (source: mappadellasalute.it).

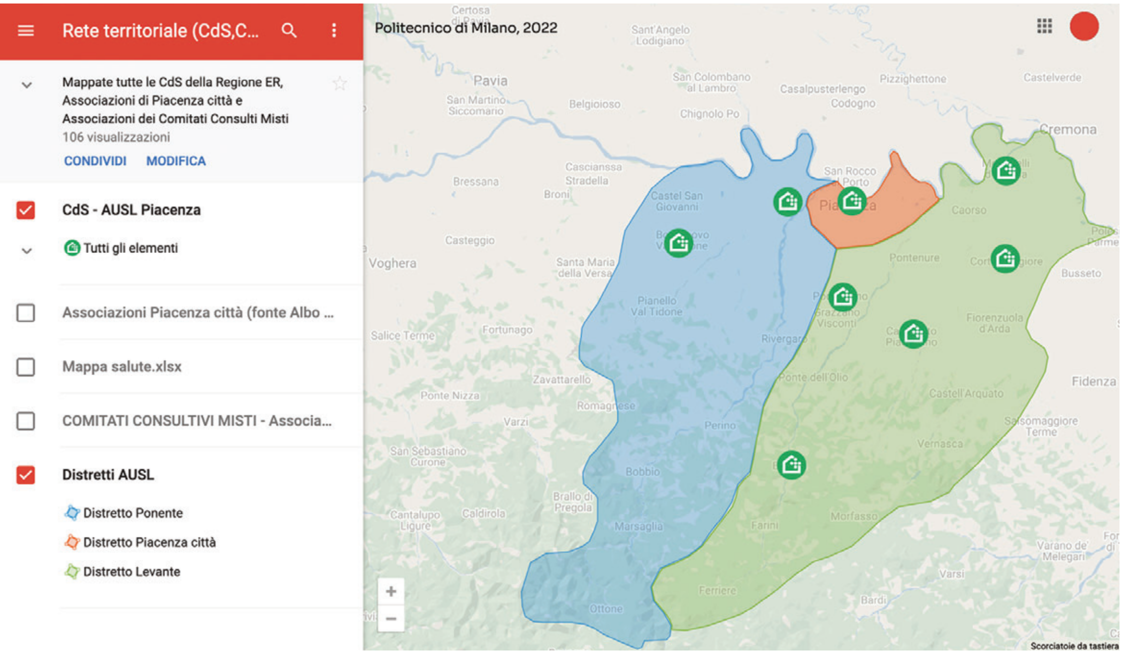
Fig. 5 | Mappe della Salute – I Luoghi per Guadagnare Salute, ARS Agenzia Regionale di Sanità, Regione Toscana, Italy (source: ars.toscana.it/mappe/mappa.php).

by the social, cultural and territorial context. For this purpose, guidelines were considered for project actions aimed at overcoming the critical issues that emerged with Covid-19, considering the aftermath of the emergency as a 'space of possibilities', a moment of reflection on the relationship between man, urbanity and identity in relation to space and territory (Piscitelli, 2019). The development of a widespread localised communication capable of influencing the lifestyles of the community was hypothesised by differentiating prevention activities into 'promotional' and 'wellness education', referring to the concepts of Urban Health and Health in All Policies[2]. This hypothesis featured the CdS as a fundamental subject and crucial actor in the prevention network. Central insofar as it attracts, gathers and synthesises the health services in the area; widespread insofar as it weaves a hybrid network (both digital and physical) that spreads out to reach other realities, including the various health centres, third sector associations and health promotion projects. The issue regarding the absence of a territorially-based comprehensive view emerged both as a communication problem and a research question.

Methodology | The first objective of the research was to define the essential tools to address the need to refer citizens to the categories of health referrers who are active in



Figg. 6, 7 | Atlas of Caregiving's CareMaps (2018), AARP and Santa Barbara Foundation, designed by Studio Accurat (credits: Studio Accurat; source: atlascaremap.org/map).



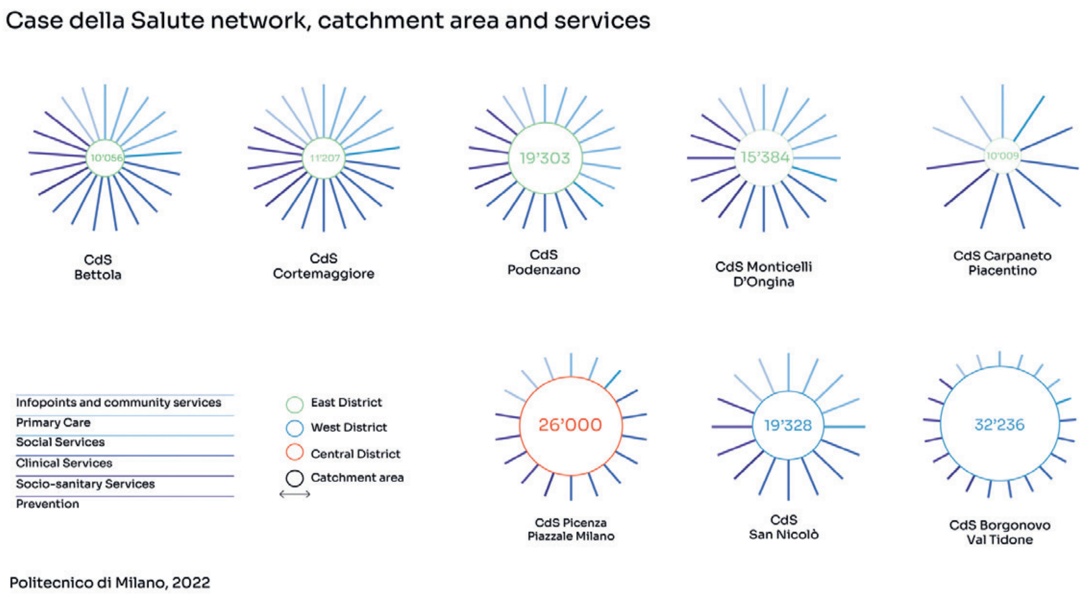


Fig. 8 | ProgettoColtivare_Salute.com (2022), designed by the Department of Design, Politecnico di Milano, Italy (source: google.com/maps/d/u/0/edit?hl=it&mid=1iFKMobDK4hS2eAwqHR8qgNNbb4lUnLuI&ll= 43.08225791752247%2C11.908045099999967&z=7).

Fig. 9 | ProgettoColtivare_Salute.com (2022), designed by the Department of Design, Politecnico di Milano, Italy.

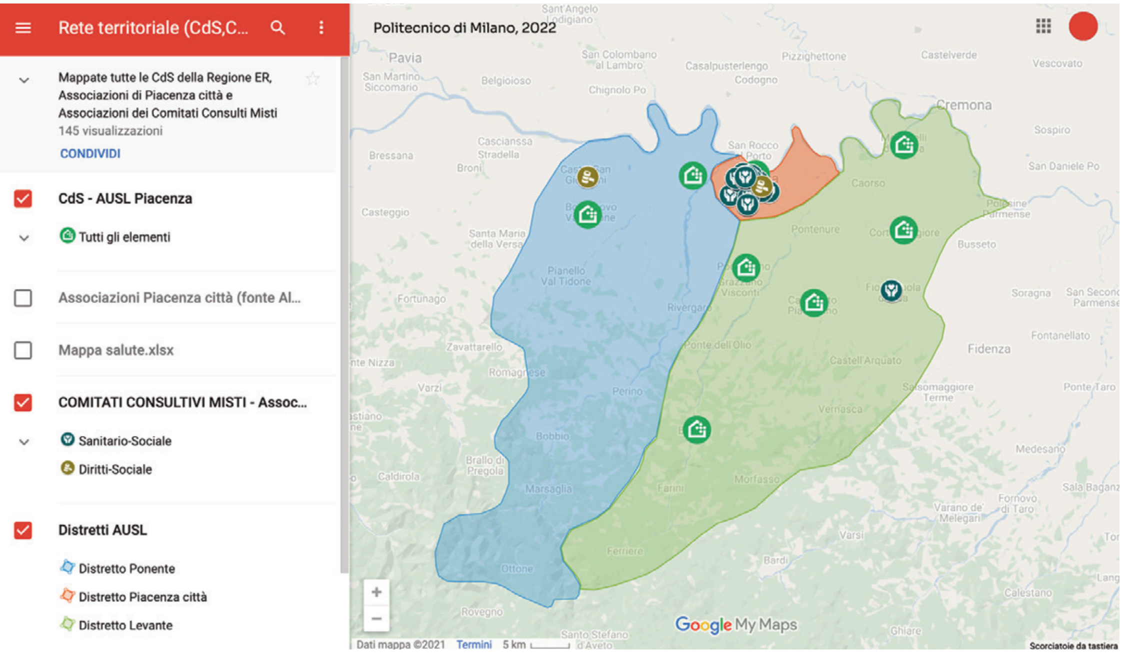
disease prevention. The use of cartographic devices – such as digital maps – for the geo-localisation of prevention-oriented health realities revealed a very high number (divided into subsystems) of categories of bodies, which are often disconnected from each other; it was therefore deemed necessary to reinterpret the roles between localized health structures. The definition of communication guidelines was developed with the project hypothesis of offering greater transparency regarding the prevention programmes within the territorial network. The network of relations used as a case study was that of the Emilia-Romagna and Piacenza CdS, already the subject of study of the Polisocial project and characterised by a widespread activity of support to citizens in their health journey. It was possible to observe the participation of numerous associations with a fundamental and diversified role.

The analysis was developed in two prevalent activities. Firstly, shared values for effective prevention, wellness and health communication were identified based on the study of the Prevention Plans and health promotion systems in Italy and abroad. Case studies were then collected for a 'multi-criteria' analysis of communication tools. Secondly, a punctual exploration of the territorial fabric of Piacenza was conducted to identify the operational relationships among the actors in the health, social and cultural network acting in synergy with the CdS. Current systems and processes for community engagement were assessed and information recipients were analysed.

The first apparent shortcoming is the absence of a useful system to clearly understand the relationship between physical places, territory and services. Therefore, guidelines were drawn up to communicate presences, roles, activities, and relationships on a cartographic basis. This information represents the first step in strengthening the process of 'empowerment' of the community and social actors, with the aim of establishing an explicit synergy, previously absent during the Global pandemic. A weakness has been also revealed through the absence of guidance and indications for citizens relating to active services and their physical presence.

Following the configuration of the role of Communication Design, intended as 'facilitator of access to opportunities for knowledge of prevention activities and connector of the network of relations', criteria were outlined for the representation of territorial hybrid relations[3] (Quaggiotto, 2017), i.e., both physical and digital. Therefore, a scheme was defined that reconstructs the relationships that support the relationship between the community and the CdS, proposing devices and languages. Hence, a framework was defined to reconstruct and support relationships between the community and CdS, proposing devices and languages. Rethinking a communicative model for health, so that it does not remain confined to identity redesign and wayfinding, means defining flexible digital publishing formats since every territory is different. It is essential to investigate the activities of territorial realities to identify relationships with the public health system and specific prevention goals.

Following the analytical reconstruction phase, the hypothesis of an 'explicit health network' was put forward: a transparent and detailed reconstruction of the essential re-


Rete territoriale (CdS,C...
Mappate tutte le CdS della Regione ER, Associazioni di Piacenza città e Associazioni dei Comitati Consulti Misti
145 visualizzazioni
CONDIVIDI
CdS - AUSL Piacenza
Tutti gli elementi
Associazioni Piacenza città (fonte Al...
Mappa salute.xlsx
COMITATI CONSULTIVI MISTI - Assoc...
Sanitario-Sociale
Diritti-Sociale
Distretti AUSL
Distretto Ponente
Distretto Piacenza città
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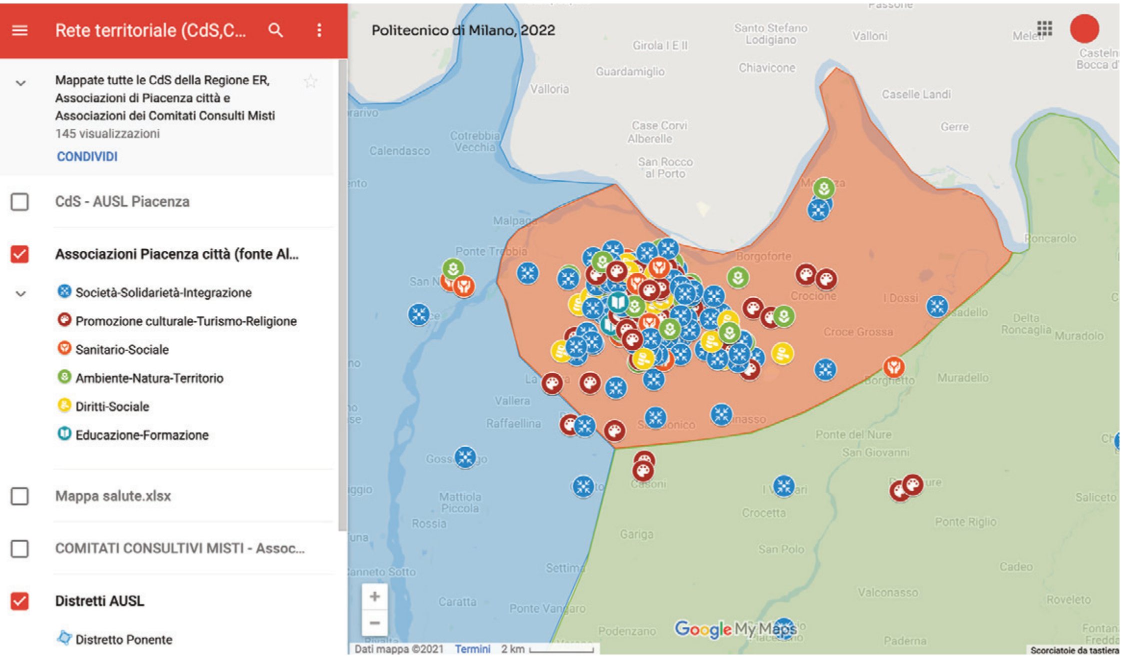
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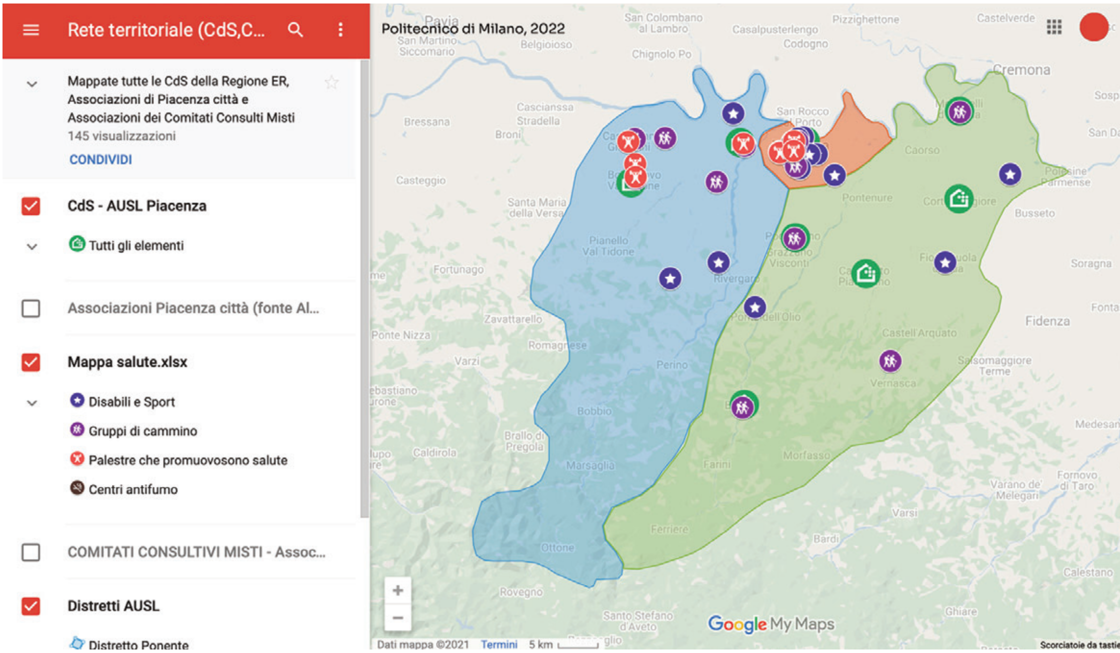


Figg. 10-12 | ProgettoColtivare_Salute.com (2022) designed by the Department of Design, Politecnico di Milano, Italy (source: google.com/maps/d/u/0/edit?hl=it&mid=1iFKMobDK4hS2eAwqHR8qgNNbb4lUnLuI&ll=43.08225791752247%2C11.908045099999967&z=7).

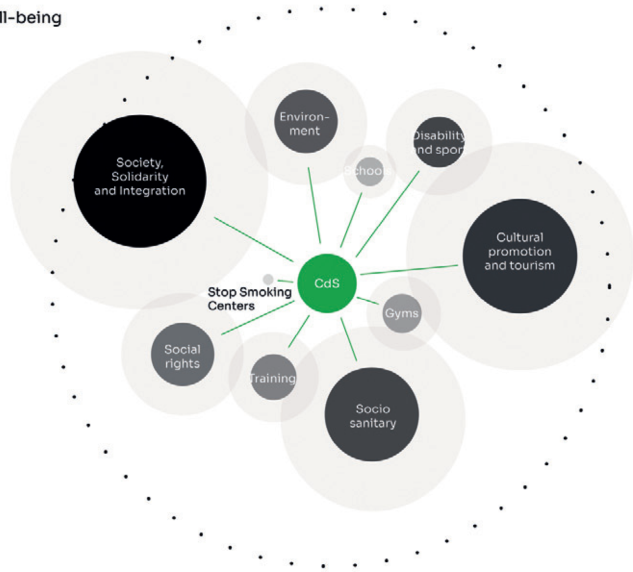
lationships for health, identified in the social space. Therefore, the guidelines point, for the surveyed territory, to the creation of communication formats that integrate analogue artefacts, physical places and digital spaces to provide citizens with ‘geo-referenced information’. To strengthen the pivotal role of the CdS in the territory it is necessary to clearly highlight its role in relation to the territory and the other health places. In other words, in order to understand the role of the CdS, it is essential to consider the socio-demographic features of the ‘landscape’ in which it is placed, highlighting the contextual relations.

The research project aims to restore the extensiveness of relationships in order to enhance the interconnected and interdependent potentials and opportunities for health, to define a communicative system that activates confrontation between institutions and promotes ‘apomediation’ among territorial actors[4] (Eysenbach, 2008). Eysenbach is among the first to affirm the importance of the role of apomedation for ‘conscious’ health, also by employing the evolution to Medicine 2.0. Apomedation structures direct communications, embedded in the territorial web. It is conceptualized as an active tool, a bridge between citizens and health actors, thus no longer exclusive and unidirectional (as simple mediation would be), but rather as a mediation of relationships on

Casa della Salute as a central hub of a capillary network

Data syntesis of CdS' sociosanitary,social, cultural well-being network in Piacenza districts.

Type	n° of actors
Society, Solidarity and Integration	184
Cultural promotion and tourism	126
Sociosanitary	94
Environment	48
Social rights	45
Disability and sport	26
Training	22
Gyms	13
Schools	9
Stop Smoking Centers	1

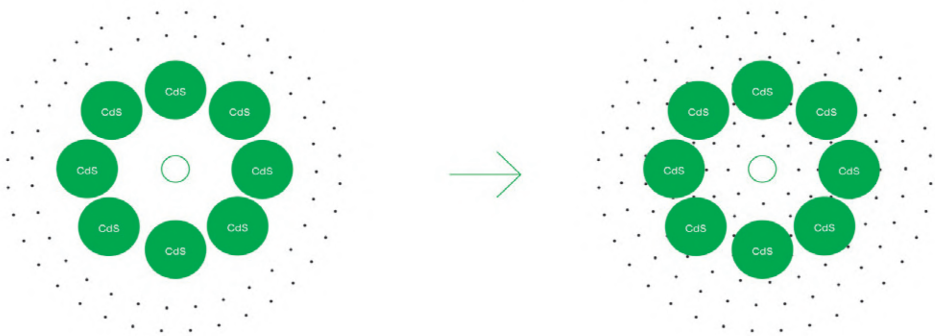


Politecnico di Milano, 2022

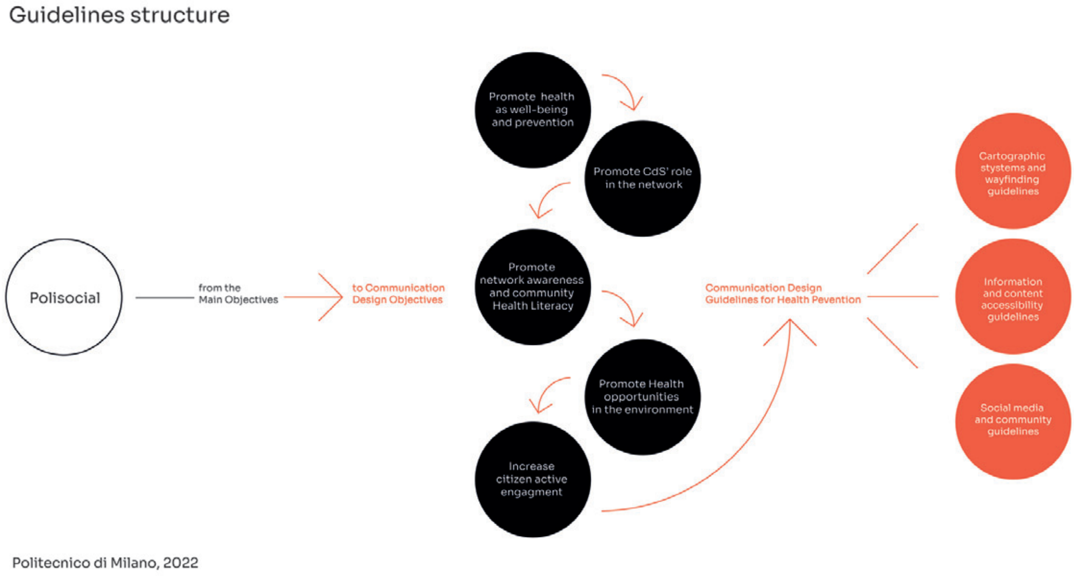
Central role of the community

from
CdS as a center in the territory: a reference point for citizens' well-being and health

to
Citizen as a center in the comunication system: communication is designed for people's needs (user centered)



Politecnico di Milano, 2022



Figg. 13-15 | ProgettoColtivare_Salute.com (2022), designed by the Department of Design, Politecnico di Milano, Italy.

the territory. From a project perspective, it entails studying communicative artefacts and channels that activate an 'apomediated' exchange in a communicative apparatus, effective in translating territorial complexities and relationships between healthcare systems. In other words, at the base network of information and relationships, the design considers both physical and virtual contact and access channels (tools, languages and devices), interpreting the needs of the different actors involved and orienting them towards knowledge in the sense of Health Literacy and prevention.

Communication for Health | Communication in the healthcare field refers to two types of activities that are distinct from each other. 'Healthcare communication' focuses primarily on services and performance in all levels of care: diagnosis, treatment and rehabilitation. Health Communication[5] focuses on prevention, to create more favourable conditions for health through information, communication and healthy lifestyle initiatives. Prevention involves several key players: Bodies, Institutions, Third Sector Associations and citizens, leading them to be active and aware stakeholders in the participation journey towards the 'social construction of health'. Communication for health, therefore, aims to inform, influence and motivate individuals, institutions, and society as a whole on socially relevant health issues. The choice determines the realization of a multi-level communication, strongly anchored in the environmental, territorial and social context of reference, taking into account the demographic fabric, the care of the environment and the configuration of the territory. Kreps and Thornton (1992, p. 2), define Health Communication as «[...] the way we seek, process, and share health messages».

The long-term goals of the research project include initiating a process of analysis that addresses how individuals 'seek', 'process', and ultimately 'share' health-related messages. This process identifies citizens who are no longer passive receivers, but subjects directly involved in seeking information and conveying health experiences. It also involves health professionals, who must become more aware of the impact of these messages, especially when they include critical issues to be acknowledged. Also of fundamental importance for citizen engagement is the process through which the user perceives information. Here again, it is possible to distinguish two different approaches. According to Roxanne Parrott (2009, p. 21), healthcare communication uses a statistical approach (data and numbers), while health communication uses a narrative approach (stories and narratives).

The second, called Social Constructionist Models of Communication, considers relational and empathic communication built through shared experience: storytelling, dialogue and emotional sharing influence the health status of individuals. In accordance with Parrott, human beings should be considered essentially «[…] homo narrans, storytelling beings». This narrow definition of the concept of Health Communication allowed the identification of the project objectives and determined the collection of Italian and international case studies that reflected the analysed concept.

The Prevention System and Case Studies | Prevention is recognised as a cornerstone of contemporary health policies; a 'programme', so defined as early as the Ottawa Conference in 1986, which, within the National and Regional Prevention Plans, is indispensable today following the pandemic phenomenon. These documents were analysed to identify points of convergence with Communication Design. The analysis revealed pivotal values useful in designing for health and well-being:
– participation as a generative tool of 'empowerment'[6]; health promotion that involves all the resources of the territory, to foster the process of strengthening the conscious role of the citizen and, by reflection, of the community;
– communication as an access tool for services and the network of relationships; it ensures that all individuals are guaranteed the same opportunities for access, fruition, quality and prevention; an 'accessibility' which is not only medical, linked to a disability, but intended in a broader, social[7] (Greco, 2016), and above all communicative sense; it is necessary to facilitate the creation of 'inter-institutional' networks and collaboration between organizations and citizens, in order to map healthcare opportunities in the territory;

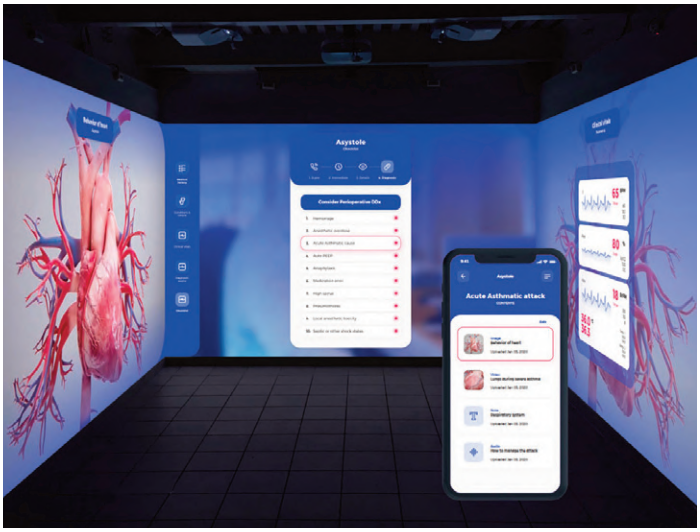


Fig. 16 | SurLive, the medical app for the simulation of emergencies in virtual environments (2020) by Chiara Venica, Department of Design, Politecnico di Milano, Italy (credit: C. Venica).

– the central role of the individual and of the communities: communication needs to be designed not only as a tool for information but also for ‘transformation’, so that citizens can acquire Health Literacy skills and become active and participating subjects «[...] Building trust and engaging with affected populations» (WHO, 2017, p. 10);
– communication as an effective promotion of participatory well-being; communication as a means of sharing within the community with the aim of orienting and motivating people, promoting pro-health attitudes.

For the design investigation related to Health Communication content, a sample of about 30 case studies, classified into project types, was collected. eConsult (Fig. 1), an English remote medical counselling platform, and Community Living Well (Fig. 2), a psychological support platform that according to the e-community model focuses on sharing experiences and stories related to health, were both among the various examples of telemedicine and health promotion through experience sharing, aimed at active patient involvement. Another type, on the other hand, concerns spatial mapping platforms. ‘Health maps’ are cartographies of territorial representation that amplify the possibilities of health promotion and user involvement (engagement), similarly to the Emilia-Romagna Region and Tuscany Region projects (Figg. 3-5).

Finally, the third type of particular interest concerns interactive maps that abstract from the territory, representing services as they relate to the individual user. The Atlas of Caregiving’s project, CareMaps, designed by Studio Accurat for AARP and Santa Barbara Foundation (Figg. 6, 7), was of particular interest. The innovative elements taken into analysis here relate to the project’s effectiveness in promoting the individual citizen’s initiative, involving them more within their health support network while helping them visualize that network within the platform to facilitate access to services and increase empowerment. Atlas of Caregiving's, in fact, is a conceptual map-diagram that, on an individual level, shows the support from family, friends, and the community surrounding the user; in the aggregate, however, the collection of data specific to the individual's experiences highlights issues and vulnerabilities in a localized geographic context. The intuition of such a design for raising the individual's awareness regarding their own health network is particularly effective in the research conducted by the Polisocial project, which nonetheless aspires to develop guidelines that have consistent directions with places, media and devices that involve the entire community, and thus are less individual and more relational.

Accessible territorial and digital networks: Communication Design for community well-being | The research was defined by analyses that effectively went far beyond the spaces of information and promotion. It focused on the potential provided through the definition of a tool useful for making the network of territorial health relationships explicit and accessible to citizens. People's well-being, in fact, is determined not only by services but also by the reality and contacts present in the territory, as well as by the ability to manage emergencies and knowledge of the possibilities offered by facilities in terms of prevention, treatment and care.

The phase of collecting data regarding ongoing prevention actions in the CdS was extended to autonomous external actors in Piacenza, hypothesizing the relationships between services on a cartographic basis, to understand the organization of actions aimed at healthy citizens. The areas pertaining to the Piacenza AUSL, including the currently active CdS, divided into the three different districts, were mapped to create guidelines for communication design (Fig. 8). Figure 9 illustrates the demographic characteristics and conformation of the observed CdS. The Piacenza area quite evidently presents a rich associative fabric. The Mixed Consultative Committees were identified, in the reconstruction of territorial relations, as the main interface body with the citizen and the territory (Fig. 10). A subsequent broader survey identified places of well-being promotion and health education, which represent 'non-health' opportunities that can contribute to maintaining a healthy lifestyle and preventing illness, starting from primary and secondary school (Register of Associations of the Municipality of Piacenza; Fig. 11). Figure 12 shows the overall data collected regarding the different actors involved: the public sector, volunteers, voluntary associations and private 'non-profit' entities, places of well-being promotion and health education.

What had emerged from the exploration of the physical territory at the beginning of the research was confirmed with the representation of the connections on a digital map. These are actual connections between realities, including very different ones, that gravitate around the CdS in an extremely extensive network. Making such connections visible clarified how the opportunity to share knowledge with citizens increases participation in activities, spreading awareness regarding the presence of a network of professionals available for care, and simplifying access to prevention services.

Conclusions and guidelines for territory with accessible healthcare | Having accepted the role of the CdS as a key node in the wellness network (Fig. 13), the communication project's underlying hypothesis acknowledged the need for a territory-based approach (physical and digital) capable of explicitly articulating the wellness network, while also envisaging the involvement of the 'healthy' citizen and the value of prevention. In this context, the designer takes on the role of 'mediator' in the relationships between the user, the health context and the territorial offer. The (dialogic) concept of apomediation, therefore, redefines the responsibility of communication as a bridge not only between doctor, patient and researcher but also and above all between technical information and possible prevention information aimed at the citizen of a specific territory and assigned local healthcare facility. Based on the implemented experience, the research aims to establish a new focus: the CdS within the territory shall correspond to the central role of the citizen in the communication framework (Fig. 14).

Following the conclusion of the studies conducted on the territory, the Design Guidelines for a map-based interface for the use of data and information are embedded within the overall project, which involves immersive and interactive remote digital tools, on-site interventions on the territory and the use of social community channels for citizen engagement (Fig. 15).

A consequent future step could consider the use of 'hybrid' immersive spaces widely distributed throughout the territory, such as CAVE – Cave Automatic Virtual Environment (Fig. 16), information-containing rooms capable of evoking experiential and substantive aspects of the real world (Gaba, 2004) for greater empathic-emotional involvement of the citizen in his or her healthcare territory. By raising awareness of the citizen's visible and accessible territorial offerings, the project aims to promote a renewed vision of the concept of prevention for health and well-being, through the offer of healthcare and social services.

The issues encountered in the study are those most closely related to the representation of the relationships between the other actors in the network: a limitation related to the need to highlight not only the 'functional', physical and tangible relationships, but also all the underlying collaborations in the territory that orient the citizen towards the experience of prevention and not just towards subsequent healthcare. The Piacenza case study represents a starting point for a broader investigation, in which the supply of health and prevention services is to be further investigated along with the physical location in the territory of healthcare spaces and their impact on the social sphere. In order to understand how to use services in an explicit strategic circuit, which is no longer primarily the prerogative of experts in the field, and to orient the citizen in the territory, it is necessary to develop a unified and widespread communication strategy, one that restores an active role to the citizen: apomediated and therefore collectively participated in, but also relational, exploring the potential of networks between physical and digital structures.

Notes

1) According to the Italian D.L. July 10, 2007, the Casa della Salute (CdS) in Emilia-Romagna (Italy) is a multi-purpose facility capable of delivering within a single physical space the full range of social-health services, promoting, through the spatial contiguity of services and operators, the unity and integration of essential levels of social-health services. More details can be found at: gazzettaufficiale.it/eli/id/2007/10/10/07A08580/sg [Accessed 28 September 2022].

2) A public policy approach across all sectors that systematically considers health in policy decisions, seeks synergies and avoids harmful health impacts in order to improve population well-being and health equity (WHO, 2014).

3) Hybrid territory is simultaneously made up of physical and digital elements; the blending of analogue and digital integrates traditional forms of territory, community, and sociality into hybrid forms of social fabric that live simultaneously online and in the streets (Quaggiotto, 2017).

4) According to Eysenbach (2008, p. 5) «[…] apomediation means that there are agents (people, tools) which stand by (Latin: apo- means separate, detached, away from) to guide a consumer to high-quality information and services without being a prerequisite to obtain that information or service in the first place, and with limited individual power to alter or select the information that is being brokered».

5) For more information, visit 'Guadagnare Salute – Rendere facili le scelte salutari' at the webpage: salute.gov.it/imgs/C_17_pubblicazioni_605_allegato.pdf [Accessed 23 August 2022].

6) Rappaport (1987, p. 122) defines 'empowerment' as a process through which individuals, organizations and communities gain greater control over issues vital to them, while Zimmerman (2000, p. 46) conceptualizes three different levels of 'empowerment' development in society: individual, organizational, community. This principle is the basis of the 'Progetti di Empowerment di Comunità, Programma n. 2, del Piano Regionale della Prevenzione – Costruire Salute 2015-2018 – Emilia-Romagna' available at the webpage: partecipazione.regione.emilia-romagna.it/iopartecipo-piazze-chiuse/costruire-salute/costruire-salute-piano-regionale-della-prevezione-2015-2018.pdf/view [Accessed 23 August 2022].

7) The concept of 'accessibility' is not intended as related solely to physical or psychological impediments (a medical concept), but rather to the difficulties of cultural inclusion dictated by the material and immaterial conditions of society itself (Greco, 2016).

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DIGITAL DESIGN, TECHNOLOGY AND SUSTAINABLE IMPACT
From apparent contradiction to strong coalition

Irene Fiesoli, Eleonora D'Ascenzi

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ABSTRACT
Design, through its ability to predict future scenarios, has the role of meeting the challenges posed by current digitization in relation to the apparent dichotomy with the sustainable dimension. This aspect is explored in the article through the analysis of the SMAG and COLUX projects. The first develops a product-service system equipped with an advanced technological set-up capable of controlling the vital parameters of green spaces. The second designs an innovative platform for creating virtual environments for co-designing products and living spaces using AR and VR. The main focus of the projects concerns the innovation of the design/management process in real time of the services through direct comparison with the actors involved in a perspective of environmental, economic and social sustainability. Such research emphasizes the importance of the repercussions of digitization and the role of design in a 'digicircular' transformation framework aimed at increasingly sustainable practices.

KEYWORDS
digital sustainability, smart system, co-design, collaborative platform, service design

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The forced distance, the forced absence of human relationships and the economic-social hardships resulting from these years of the pandemic have made it clear, now more than ever, that we are part of a community with a common destiny and that everyone is responsible for each other in this system based on reciprocity that gives rise to an intertwined network where each node contributes to the sustenance of the others, consequently leading to the achievement of systemic and collective well-being. The condition of isolation that we had to endure 'took our breath away', but nevertheless gave 'relief' to our planet (Dellink et alii, 2021). All this can do nothing but place us in front of the evidence that our presence, voluntarily and involuntarily, is guilty of numerous and serious damages to our ecosystem. During the two months of isolation, we were able to witness the phenomenon of re-appropriation of space by the natural ecosystem, which thus highlighted how the absence of human disturbance represents a positive aspect for the surrounding environment.

This consideration leads to rethinking the acts conducted at the expense of the natural environment and regaining a regenerating contact with it. If plants are the only living entities capable of naturally producing oxygen, it is obvious to think that their presence in the world – as well as having to become ever greater – will lead to greater human well-being. So nature, and particularly the relationship through which we live in contact with it, will have to be the starting point for any project or political action (United Nations, 2015). It is precisely from this need to restructure a new relationship with nature that the research project SMAG – Smart Garden was born, developed to improve the management of green spaces within cities and domestic spaces by trying, through the use of advanced technologies, to make humans communicate with their plant surroundings by giving 'voice' – in the true sense of the term – to plants.

From this project in which the research group of the Laboratory of Design for Sustainability of the University of Florence (Department of Architecture) was able to experiment with the potential that digital technologies have, if used consciously, to produce strong effects in environmental terms, the idea was born to try to experience how the same approach could also adapt well to relational dynamics between people, especially in the workplace. The COLUX (CO-design platform using Mixed Reality for the LUXury interiors sector) research project is based on this last reflection, which develops starting from people's needs to structure new channels for communicating, creating digital and virtual workspaces aimed precisely at sharing and co-designing. The two projects – presented in detail in the following paragraphs – thus aim to explore how it is possible to develop a future design that, exploiting the application of contemporary innovative technologies, helps to facilitate the dialogue between the actors present in our ecosystem, in the double relationship of Human-Nature and Human-Human.

In both projects, an element of analysis that was extensively covered was the application of high-tech solutions to solve the starting problem. Indeed, rapid technological development and the increasingly totalitarian presence of digital solutions lead us even more often to identify, in some cases erroneously, innovation with the technology itself. This becomes a fundamental piece of the innovation process in all sectors. In reality, Digital Transformation, while having the power to change the meaning of things (Epifani, 2020), needs to cultivate a strategic vision of systems and scenarios that can only be realized through the application of a creative process. Designers, thanks to their ability to see, show, predict (Zurlo, 2012) and plan the future, thus have in this context the role of taking the challenges posed by digital evolution and translating them into concrete systemic actions. Developing digital projects means developing strategic projects that exploit technology as a tool to support the result, and which must therefore be based – to have an effective scientific value – on a whole series of methodologies and processes that have been refined over the years, such as User Experience Design, Service Design, Co-Design, and Design Thinking.

In addition, in both projects, the issue related to the use of digital technologies by the end user emerged strongly. Telematic technologies today certainly make it possible to greatly reduce the organizational congestion of daily life, reducing travel to workplaces, shopping malls, banks, etc., thus ensuring the possibility of using a service in a 'remote' mode.

But when do people use a digital system or service? And again, when are the technological innovations we use really in line with our daily or work activities? Are we, perhaps, simply 'forced' to use them? We have tried to answer these questions through the projects presented, precisely moving from the desire to develop in each of them new ways related to interaction with green spaces and work. In the future, strongly useful as well as innovative services can be designed, contributing consciously and strategically to a development process that will be inevitable as well as unavoidable. An example can be found in Senseable City, where the replacement of the term smart highlights the need to consider technology precisely as a medium of the relationship between inhabitants and space, understood as a hybrid entity at once physical and digital (Ratti and Claudel, 2018). Data are then considered as a real device of interaction between the aforementioned superstructure and users/citizens, understood both as users of services, but also as actors of them and especially as 'human capital of knowledge (OECD, 2007) useful for their design' (Formia, Ginocchini and Ascari, 2021).

The integration of users as co-producers in local, national, and European service and policy development processes is also required today at the institutional level, as evidenced, for example, by the European Green Deal (European Commission, 2019). For this reason, it is fair to say that such integration must necessarily be one of the fundamental steps (picking up from participatory or Co-design methods) for any project development methodology to be implemented, especially when the project output is a highly technological or digital product or service. The role of fostering forms of human-centred development is therefore recognized to the culture of the project, as hoped for at the beginning of the formation of the New European Bauhaus (von der Leyen, 2020). Thus, we understand the relevance of the reasoning and the importance of deepening the evolution of the relationship between data, environment, design and

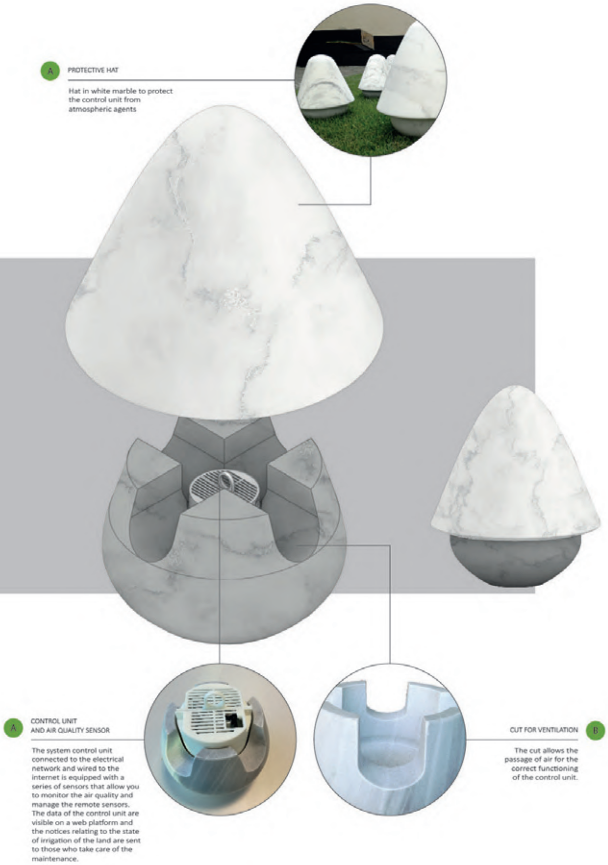
Fig. 1 | Smart System (credit: I. Fiesoli, 2018).

people for the conception of services aimed at the development of an ecosystem (including production) of the future, oriented toward social, as well as environmental and economic, sustainability (Formia, Ginocchini and Ascari, 2021; Fig. 1).

SMAG: the Smart Garden of the future | According to Socco et alii (2005), parks and green spaces are essential elements for the livability of cities; their quantitative increase and qualitative improvement are indicators of a city that cares about the quality of life of its inhabitants. However, the management of green spaces in urban contexts causes significant inconveniences that can be mitigated by ensuring an adequate supply of services for parks and gardens. The preservation and proper maintenance of the network of green spaces that populate cities, as well as many homes, create new environments in which people express a desire to live by fostering and ensuring the regeneration of the ecosystem itself. Good city management, therefore, cannot transcend its 'green' heritage and, above all, cannot disregard its nature as an ecosystem, that is, as an entity that the city environment absolutely needs to ensure the healthiest possible lifestyle for its inhabitants.

It is precisely from this need, which is now unavoidable, that the concept of the smart city (or smart city[1]) was born, based on a range of digital tools that can be used in urban settings. This solution opens the eye to new frontiers in the study of urban systems but at the same time generates new obstacles to understanding the real reasons behind the human need to live in cities. A particular ambivalence this one that leads people to want to live in contact with nature but without necessarily moving to the countryside, even though there is a trend away from large cities toward contexts with intermediate densities – small towns and suburbs (Istat, 2021) – making it even more important to protect the green spaces found in urban areas and our homes.

It is precisely on this assumption that the SMAG (Smart Garden) project was born (financed by the Tuscany Region within the RSI – POR FESR 2014-20 calls), which envisages the realization of a multi-sensor system for the detection of the main characteristics of a 'garden environment': thanks to the setting of the main parameters both



Figg. 2-4 | ‘I Sette Nani’ project by UpGroup, SMAG project (credit: A. Tanzini, 2020).

environmental and functional, it is able to implement strategies for the qualification of such environments by those involved in their maintenance, becoming a professional tool of support for companies operating in the efficient and optimized management of public and private garden areas.

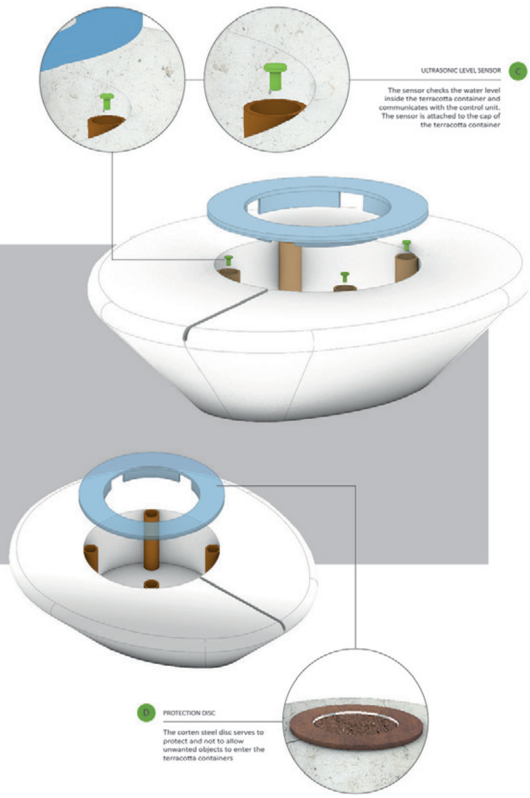
From a technical point of view, the project leads to the development of a system of sensors and actuators placed inside furniture that, once positioned at particular points in the garden, are able to send data to a platform via a control unit. This management platform collects data from the control unit, records it, and analyzes it through advanced algorithms, creating a link between the garden's performance and the entity managing its maintenance, enabling predictive management of maintenance issues and consequently increasing the level of well-being and comfort of people and plants.

The challenge of the project was to use advanced sensors to attempt to detect the different aspects that can be monitored within a garden, such as: external environmental conditions (temperature, humidity, pressure, CO_2, particulate matter); soil conditions (moisture, density, PH, organoleptic composition); plant conditions (growth status, presence of problematic elements such as insects, poor plant structure); remotely accessible information, images, noise; and implementation of actions through electronic actuator apparatuses (irrigation, soil or plant nutrition, etc.).

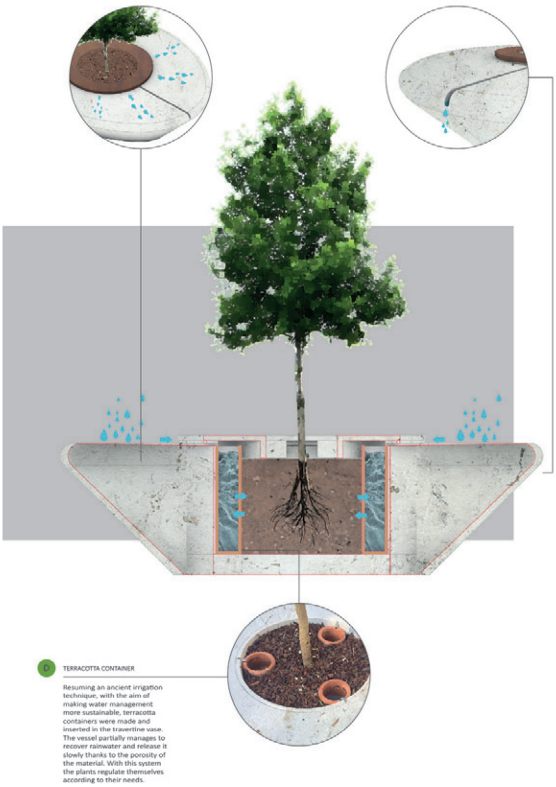
In particular, in the SMAG project these specific sensors are included in design products such as stone outdoor furniture systems and furnishings, produced by Travertino Sant'Andrea and UpGroup: I Sette Nani (in marble) is a collection of products designed for the private sector, in which each dwarf has a specific control and detection function (Figg. 2-4). Water Value and Litus (in travertine), on the other hand, are a series of urban design seats/pots and develop a system that reclaims ancient irrigation techniques, which involve capillary irrigation using terracotta jars placed inside a pot. At the top end of the jars, there is an ultrasonic sensor, connected to the rest of the system, capable of monitoring the quality of water available. If necessary, it alerts the garden manager or activates a valve that fills the pot directly from the water system connected to the pot (Figg. 5-9).

In addition, the SMAG project develops a system of sensors and actuators that send data to a specific platform through a control panel, based on various wireless and wired access technologies. The management platform collects data from the control panel, records it and analyses it through advanced algorithms. These detect the performance of the monitored green areas to manage, in a predictive and systematic way, the issues of maintenance processes of these spaces, whether public or private. Through this app, connected to the control panel, the different products actually become smart and are able to relate to the different actors who interact with the system: on the one hand, with the maintainer for aspects that concern the health and maintenance of green areas, and on the other hand, with people from an emotional/experiential point of view, raising awareness about green areas and how that particular place contributes to the improvement of our ecosystem (Marseglia, 2020; Fig. 10).

A
SOIL MOISTURE SENSOR
The WATERMARK is designed to be a permanent sensor, placed in the soil to be monitored and "read" as often as necessary with a portable or stationary device.
CONTROL UNIT AND AIR QUALITY SENSOR
B
The system control unit connected to the electrical network and wired to the internet is equipped with a series of sensors that allow you to monitor the air quality and manage the remote sensors. The data of the control unit are visible on a web platform and the notices relating to the state of irrigation of the land are sent to those who take care of the maintenance.



ULTRASONIC LEVEL SENSOR
C
The sensor checks the water level inside the terracotta container and communicates with the control unit. The sensor is attached to the cap of the terracotta container
D
PROTECTION DISC
The corten steel disc serves to protect and not to allow unwanted objects to enter the terracotta containers



D
TERRACOTTA CONTAINER
Resuming an ancient irrigation technique, with the aim of making water management more sustainable, terracotta containers were made and inserted in the travertine vase. The vessel partially manages to recover rainwater and release it slowly thanks to the porosity of the material. With this system the plants regulate themselves according to their needs.

Figg. 5-9 | 'Water Value' and 'Litus' projects by Travertino Sant'Andrea, SMAG project (credit: A. Tanzini, 2020).

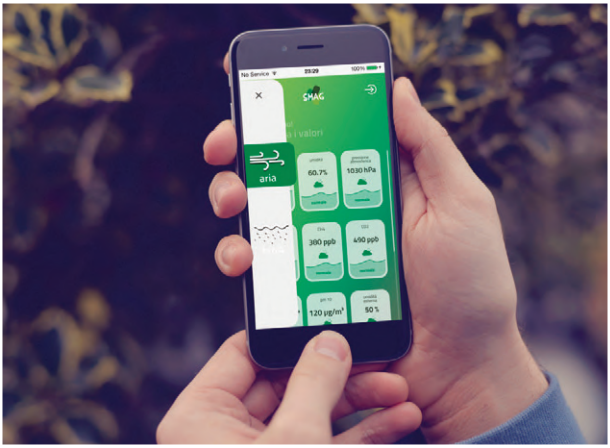


Fig. 10 | Platform interface project, SMAG project (credit: M. Sottani, 2020).

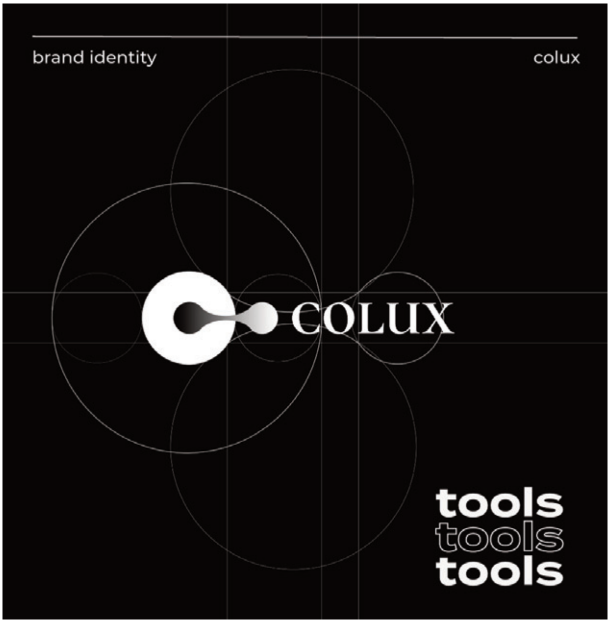


Fig. 11 | Constructive brand, COLUX project (credit: M. Costa 2022).

COLUX: a sustainable collaborative platform | Today, more than ever, companies are facing increasingly complex challenges arising from growing contemporary criticalities (Polifroni, 2021). Currently, in fact, as a result of the health emergency, traditional manufacturing companies base their competitiveness not only on the quality level of production – which by its nature characterizes them – but also on the ability to add further value to the product through the ability to respond immediately and ductily to increasingly demanding and customizable market demands. In this perspective, the digital evolution we are witnessing can contribute to a territorial development aimed at economic, social and environmental sustainability in which the world of design and production is rethought by unhinging some inefficient contemporary paradigms.

In this moment of evolution and change, digitization can therefore offer an innovative approach that can transform the limitations that the pandemic has set us into challenging design opportunities through which local realities can explore new ways of working (Covato, 2020) and managing resources by rethinking and redesigning even environmentally harmful processes (Franco and Nuccio, 2021). At the same time, such integrated services also stem from the problems encountered in the logistical difficulties of manufacturing companies, in the movement of goods, increased production costs, reduced labour capacity, increased difficulty in sourcing raw materials and delivering products, to the new ways of smart working that still show shortcomings.

From this perspective, therefore, the ability to develop integrated systems such as co-design and management platforms represent a futuristic scenario capable of responding to such needs and obtaining positive responses in relation to the entire territorial and actor ecosystem. These solutions are highly innovative not only for the end users who benefit from immediate and personalized responses but also for the business and planning teams who are thus able to relate directly with the recipients, breaking down all kinds of geographical, temporal, and communicative barriers. To this end, in recent decades, increasing attention has been paid to the accessibility of digital tools, which must be able to connect a wide pool of users (designers, companies, stakeholders, and end users) by ensuring ease of language and visualization thus eliminating language barriers and enabling successful co-design practices (Pihkala and Karasti, 2018; Venkat Ramaswamy, 2004).

In the field of design and manufacturing, objects and spaces are usually presented to end users through technical drawings, sketches, renderings that are difficult for end users to understand and/or prototypes that produce a strong environmental impact. For this reason, the scientific literature is increasingly focusing on new interactive modalities – such as augmented reality and virtual reality - enjoying great success in the market (Zhang et alii, 2020; Wang and Schnabel, 2008; Rossato and Raco, 2017). The real elements of innovation are to be found in the application of advanced features that aim to create hybrid platforms and workspaces suitable for virtual sharing and connecting spatial realities. Designers and end users can then conceive shared projects and co-designed tailored solutions thanks to the ease of communication provided by these advanced technologies.

This type of innovative platform offers a comprehensive service ranging from storytelling to sales, after-sales and management control of resources thanks to which it is possible to give satisfactory answers to the many current needs, triggering attractiveness and customer loyalty. Digital co-design is, therefore, one of the most suitable enabling technologies for Factory 4.0 that can ensure benefits throughout the entire development of product/process/factory life cycle (Urban, Krawczyk-Dembicka and Łukaszewicz, 2022). The resulting sustainability must also be understood from a social

Fig. 12 | VR Application interface, COLUX project (credit: M. Sottani 2022).

point of view, through the improvement of the end-user experience and the inclusiveness and involvement in product conception/design.

Within this context, the COLUX project – CO-design platform using Mixed Reality for the LUXury interiors sector (Project financed under the Second Call POR FESR 2014-2020, Tuscany Region) explores the potential of new technologies, applied to the practice of co-design (Fig. 11). Indeed, the project aims at the creation of a creative, virtual and collaborative space; supported by the development of an innovative digital platform where different designers can collaborate simultaneously on the project through the use of interactive AR and VR technologies leading to the creation of digital spaces for the co-design of products and living environments (Fig. 12).

The project aims to facilitate 'remote' working practices by redesigning workspaces – especially related to the world of design and manufacturing – in a virtual mode, creating a metaverse in which to develop all stages of the creative process in real-time by

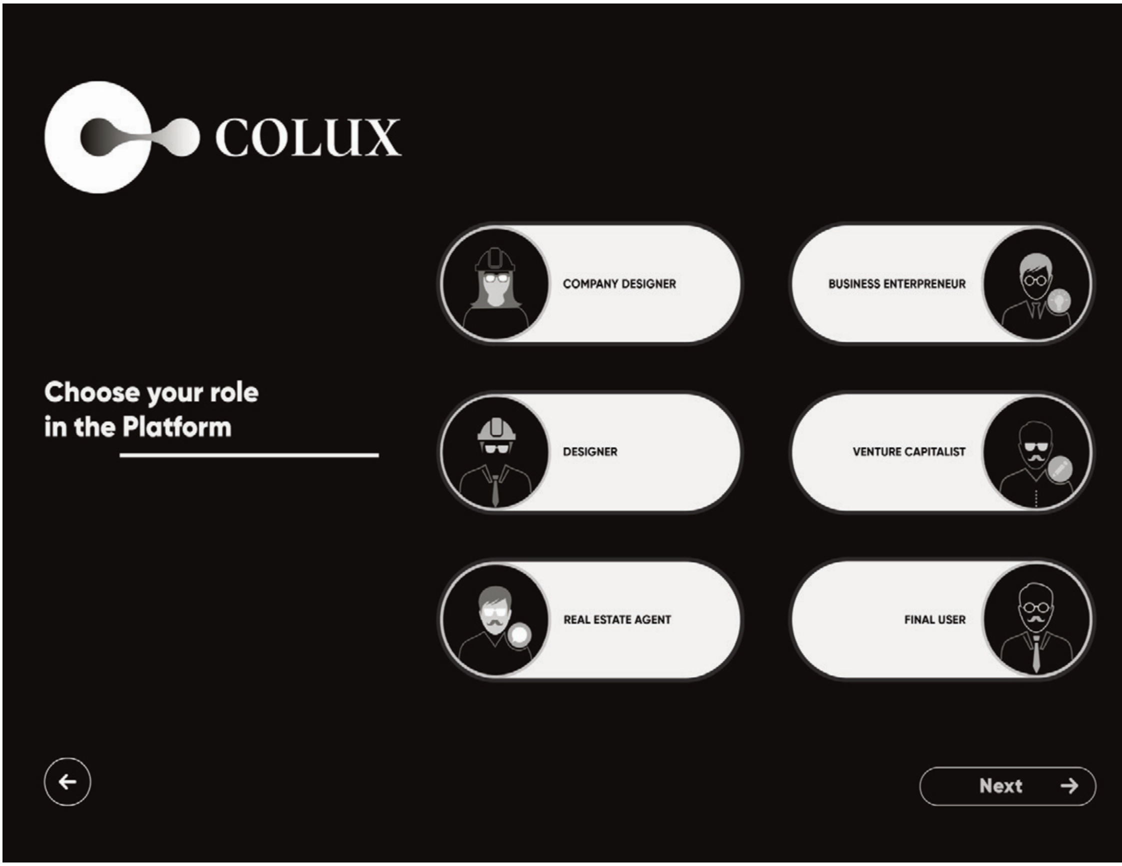


Fig. 13 | Multi-user function interface, COLUX project (credit: M. Sottani 2022).

involving the various actors. The overall system of this project works by connecting several professionals in real-time in a shared virtual workspace: a direct and fast channel that can exchange information on design project development (Fig. 13).

The work plan represents the continuum of a previous project – MixedRinteriors – which led to the definition of a virtual design asset for Unity software that enables the development of experiential builds, as well as products and environments, aimed at involving the end-user. Building on these design premises and experiences, COLUX focuses on enabling the user to view the designed space and product by interacting with it, viewing the details, modifying them, and (re)designing them carefully.

The platform allows you to create a close relationship with designers and end customers to offer high-value products accompanied by a high degree of customization and a wide range of services. The user can directly leave comments or make small changes by understanding the problems of the project, seeing the details, and creating

Fig. 14 | Interface for asset customization, COLUX project (credit: I. Fiesoli 2022).

a ‘smooth’ transition between the preliminary design phase and the subsequent executive realization. In addition, the visualization of design products and designed spaces generates a virtual catalogue that the project community can access by taking advantage of the development processes in an experimental and innovative way (Fig. 14).

From a social point of view, the community can indeed act on the platform through direct responsibilities, feeling part of a unique system. There are also no differences in terms of age, profession, type of organization, etc. Thus, there is no single user: the strength lies in the plurality of actors that populate it. This aspect, guaranteed by the simplification of technical language, is also reflected in the collaboration between designer and end user, and triggers important innovation processes on the social level as well.

All stages of the creative process thus involve the various actors with the aim, among others, of optimizing project time and costs. In light of the current environmental crisis, we are presented with a key opportunity to stimulate the reduction of resource consumption and increased awareness of ecological quality and well-being of the entire territorial ecosystem. Indeed, the virtual space of the platform avoids 'waste' by reducing the waste elements associated with the physical production of prototypes, while maintaining the possibility of digitally verifying all the technical and design elements necessary for the development of a good project. COLUX sustainability also takes into consideration the reduction of environmental impacts related to communication and especially to the exchange of data (emails, photos, reports) through the actors of the creative supply chain (designers, architects, planners, engineers, technicians, entrepreneurs, sellers and end users).

The real-time display of different digital solutions, the exchange of data, their relative storage, and the analysis of any related issues are thus a challenge of the present times for a finally sustainable digital.

Implications, conclusions and future developments | The current environmental and pandemic challenges require the project to assume a key role in experimenting with innovative solutions to achieve the goals of ecological, economic and social sustainability. With this in mind, the modus operandi of the project must therefore include, among other aspects, a focus on supporting local and collective actions of land transformation and management on multiple levels of socio-cultural, typological and environmental complexity (Errante, 2021) from which the related implications derive.

The projects described in this paper are innovative due to their sustainable effects, where the term 'sustainability' must be understood in its broadest sense, encompassing environmental as well as economic and social perspectives. Specifically, within the SMAG project, in addition to the obvious repercussions in terms of environmental sustainability – given the very nature of the project – it is important to emphasize that there are also those related to economic and social sustainability.

If the economic implications appear obvious from the point of view of saving money and time for public administrations thanks to the programmed maintenance of green spaces in a customized and targeted way according to the 'manifested' need detected by the sensors on the platform; equally fundamental are the spin-offs in terms of social sustainability. In this perspective, it should be pointed out that users are active components of the digital system since by 'living' the space they will be able to send detailed feedback on the plant state, contributing both to its maintenance, to the co-design of the service and the implementation of its functionalities. This kind of participatory approach will also ensure greater awareness on the part of users/citizens, becoming a stimulus for the development of a renewed civic sense that is environmentally conscious and thus aimed at more sustainable practices.

In parallel, the COLUX project shows its spin-offs in terms of social sustainability, through improved end-user experience, inclusiveness and involvement in product conception/design. In this perspective, the research project plays a strong innovative role: compared to platforms currently developed and released in the market, COLUX creates a collaborative and inclusive platform model with a non-hierarchical social structure, where each member is part of a community dedicated to design. COLUX also reflects the principles of economic and environmental sustainability through the reduction of costs and time associated with both the reduction of physical meetings and the transport and movement of stakeholders and business prototypes. The product customization is meeting the customer requirements through digital changes made in real-time that allows participants to connect from around the world, reducing unnecessary physical meetings and halving design time and costs as well as the cost of time to market.

From these project assumptions, it is clear that the idea is to start from the micro-scale of territorial levels (regions and municipalities) to try to activate concrete projects that are more controllable and manageable but equally lead to an improvement in terms of environmental sustainability, well-being for people's lives and management of businesses and, more generally, of infrastructure. On these three strands of development, it is safe to assume that, starting precisely from this sort of transcalar territorial acupuncture, improvements can gradually be made to the overall system, considered as a macro-area of intervention for the overall goal to be achieved.

In this sense, the projects analysed take an innovative approach aimed at experimenting with new paradigms capable of developing digital solutions – required by the contemporary world – that are compatible with the environmental and social needs of the territories in which they are applied and tested, as well as of the users. In particular, the presented projects become a direct strategic channel for the exchange of information on design project development (COLUX) or green space management (SMAG).

The benefits derived from the proposed solutions represent the influence of virtuous design on the development and management of digital processes capable of achieving positive effects on the entire territorial and social ecosystem, thus overcoming the apparent dichotomy between the terms 'digital' and 'sustainable'. The territorial spillovers of the case studies are thus to be understood in light of their design capacity to create replicable and scalable best practices. In fact, both projects enable the exploitation of digital tools for the creation of a conscious, sustainable, circular, inclusive and active supply chain by emphasizing how the digital and physical scenarios can concretely interface with each other.

In the case of the COLUX project, the beauty, knowledge and 'philosophy' typical of the chosen territory are shared globally, creating working connections through the use of innovative technologies that support the growth of manufacturing companies in terms of sustainability. In the case of the SMAG project, on the other hand, technology contributes to the control of the vital parameters of green spaces, supporting a product/service system capable of reformulating its management in terms of quality offered and capacity for innovation.

Scientific impact is to be understood in reference to the approach used in the two case studies, which, although with different results, brings out the opportunity to experiment with new combinations that aim to use digital tools to develop sustainable projects and to make the community more inclusive and aware. From a theoretical point of view, the methodology used in the two case studies, linked to the needs arising from specific real needs and the resolution of related spatial issues, represents a high degree of reproducibility and scalability in other international scientific contexts.

Finally, from the reading of the projects presented, it is possible to consider their future potential and limitations. Both kinds of research, based on the relationship between digitization, sustainability, and community, constitute a driver toward the creation of future digital scenarios capable of focusing on the sharing of civic values concerning environmental heritage.

The limits of these design approaches, however, are to be understood both at the level of effective environmental sustainability and at the level of a lack of community education in digital innovation. From the first point of view, the difficulties are to be found, among others, in reference to the complexity of the relationship between growing contemporary digitization, fuelled by large amounts of hard-to-store data (i.g. big data), and the parallel need to streamline these volumes to reduce emissions. In the not-too-distant future, we will likely be talking about the digital waste that needs to be disposed of and data centres that can no longer maintain the entire digital infrastructure. At this point already at the present, it is necessary to adopt a tangible evaluation system that analyses the actual benefits derived from digitization in terms of customization and material waste reduction to examine whether such design applications can be sustainable in the long term.

At the same time, from a social perspective, there is an emerging lack of real awareness related to the use of digital technologies that addresses its limitations and potential even before its adoption. The negative effects of the unconscious use of such digital tools also need to be explored and debated with special reference to the well-being of the end user. Starting from these assumptions, these environmental and social aspects, which have not yet been analysed in COLUX and SMAG, represent both the limit of research and the opportunity on which to build future planning.

It is, therefore, necessary to activate a community digitization education process that is able to provide the tools to understand how to make the best use of technology in the professional and personal spheres, especially with a view to conscious and sustainable consumption. From the design point of view, it also becomes essential to analyse the effects of the psycho-physical well-being of the recipients, already starting with the accurate analysis of their user experience and the effect of the growing loss of physical dimension resulting from the increase of such digitization. Moreover, these approaches, typically linked to design, can also be applicable in other design areas (such as architecture and urban planning) to strengthen the spillovers of such choices in an ecosystem as broad as possible.

In this sense, unexpected scenarios capable of holding together technological experimentation, ecological repercussions and social innovation can develop through an exegetical attitude that aims to interpret constant and renewed social, economic and environmental needs.

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Note

1) For more information, see the web page: ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en

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Volume no. 7 of the series Project debates the subject 'connections' between people, between people and things/places and between things/places and 'greenery' in symbiosis with the built form, two topics of pressing relevance. Concerning the first subject, the digital 'opens' by connecting (delocalizing) and 'confines', but above all, it 'induces' new spatial configurations in a constantly evolving relationship between genius loci and shape, function and flexibility of use, between the Vitruvian man, and his physical proportions, and the 'inforg' man who lives, works and relates to the contemporaneity of simultaneously physical, virtual and digital places. A space that expresses Connections: Physical, in the single material, analogical and tangible object; Virtual in configuring experiences of augmented and immersive reality, of wearable technologies; Digital in interacting and implementing new creative and communicative processes and, at the same time, technical, to control and monitor the project at various scales, conveying forms and images, functions and performances in a new dimension of digital sharing.

The relevance of the second subject is linked to deforestation and forest fires, urban sprawl, indiscriminate use of non-renewable raw materials and an increase in CO2 emissions contribute to global warming and climate change, causing a deastating impact on our fragile ecosystem, society and the economy. So, we recall the role that nature and greenery can play in the short term to address the current challenge that threatens the whole planet. It opens up to new mediations and intelligence forms borrowed from a multiplicity of living species which define and configure bio-design, bio-architecture, bio-infrastructure, and bio-city solutions. A new systemic, interdisciplinary and multiscalar logic begins to spread: from cyber-gardening to bio-technological remetabolization of whole neighbourhoods, to responsive envelope systems that integrate bio-materials and/or cultures of living microorganisms but also new opportunities for circular sustainability.

Greenery and digital technology provide many benefits for environmental, social, economic, health, well-being and quality of life aspects: their 'creative and strategic' approach can be essential for sustainable and aware development. The subjects collected in this volume, essays and research can fuel the international debate and give researchers a way to tackle the contemporary climatic, environmental and health challenges by, on the one hand, implementing 'virtuous connections' among the different stakeholders of the building process and, on the other, identifying the innovation drivers useful to spread the culture of social, economic and environmental sustainability that could favour, through conscious products and processes, the much desired digital and ecological transitions.

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