Circular economy and resources for architectural and urban regeneration projects

Chiara Moretti

Abstract: The circular economy is an increasingly common concept in urban studies that aims to create a more sustainable and efficient resource management system. While natural processes, characterised by continuous cycles, produce no waste or externalities, the contemporary built environment is based primarily on linear logic. The high technological and construction sophistication of cities, while ensuring efficiency, has led to the production of large quantities of waste, the progressive reduction of natural elements and increased urban vulnerability to climate change and biodiversity loss. In this context, it becomes crucial to rethink architecture as a discipline capable of following the same logic as nature, balancing the economics of construction with the ecology of production and regenerating the life cycles of resources.The integration of natural solutions and circular economy principles can support urban regeneration, improving citizens' well-being and health. This contribution explores urban transition processes according to the principles of regenerative design, enhancing the role of nature and the recycling of local resources for the transformation of critical areas into ecosystems characterised by the circularity of material and immaterial resource flows.

Keywords: Circular model, Regenerative design, Urban metabolism, Ecological balance.

1. Moving Beyond Growth for the Ecological Balance of Cities

Increasing temperatures, rising sea levels and ever-higher stakes mean we face a growing risk of disasters, while the impact of human activity on the environment is becoming increasingly evident. The planet is experiencing its sixth mass extinction, with over a million species at risk in the next decade. More than 90% of this loss is caused by the extraction and processing of natural resources, a direct consequence of a linear economy based on the "take-make-dispose" model. (EMAF 2021)

Natural and socio-economic systems are closely linked: economies depend on ecosystem services, but economic activities can profoundly affect ecological balances (Nassl and Löffler 2015).

In fact, in order to ensure high levels of functionality in residential, infrastructural, social and cultural areas, contemporary cities are configured as hypertrophic and energy-intensive metabolisms, characterised by high resource consumption and the production of large quantities of waste: they consume about 70% of the world's energy (UN-Habitat 2022), use 75% of natural resources (Mancuso 2023), emit 75% of CO_2 and generate 70% of global waste (Luqman et al. 2023). This trend increases the vulnerability of urban systems, reducing their resilience to the impacts of climate change and accelerating biodiversity loss.

Predictions regarding global population trends require ever-rising urban capacity, further increasing pressure on natural ecosystems. (Bardi e Alvarez Pereira 2022) Faced with these challenges, the transition to a sustainable approach can no longer be postponed.

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Addressing this crisis requires a transformative shift in production and consumption systems towards regenerative models, recognising that the circular economy is the only model capable of reducing pressure on ecosystems and ensuring long-term resilience. (UNEP 2024a). This change is at the heart of the United Nations Sustainable Development Goal 12 (Responsible Consumption and Production), whose intrinsic interconnection with other goals (including those related to life on land, life below water and climate change) highlights the synergistic nature of the transition to regenerative models. At the same time, IPBES (Intergovernmental Science-Policy Platform on Biodiversity) emphasises that genuine transformation requires profound changes in worldviews, values, social norms and governance structures, which are fundamental to achieving lasting sustainability (O'Brien et al. 2025).

It is possible to decouple economic growth from resource use and the environmental impacts that this causes. The concept of the circular economy, which promotes the reduction of waste production and resource consumption through symbiotic relationships between economic activities in closed material cycles, is increasingly cited in this debate as a framework for rethinking the ways in which cities can develop without exceeding the finite planetary boundaries that set limits on economic growth. (Williams 2021; Williams 2019). In this scenario, the adoption of circular economy models, capable of regenerating resources and reducing waste, becomes crucial for rethinking architecture and urban planning, promoting cities that are resilient and compatible with the planet's ecological limits.

In recent years, the concept of urban regeneration has evolved to take on an increasingly multidimensional and strategic dimension in response to the growing complexity of urban transformation phenomena. The Urban Agenda for the EU (2023) highlights its integrated dimension, while UN-Habitat (2022) emphasises its participatory, inclusive and resilient nature geared towards sustainability. These definitions converge in recognising urban regeneration not only as a set of physical interventions, but as an integrated process capable of addressing the challenges of ecological transition, spatial justice and social cohesion. Recognising this interdependence is essential for promoting development models that are sustainable in the long term and capable of regenerating natural resources rather than depleting them. In this sense, circular regeneration should not be understood solely as a technical operation of reusing materials, but as a reactivation of new life cycles (Bocchi and Marini 2015).

Based on these premises, the article examines how a circular design paradigm can support climate neutrality in cities and explores how architectural and urban design can contribute to imagining territorial models capable of enhancing biodiversity, local resources and nearby production cycles. Through the analysis of literature, case studies and international experiences, a reflection is formulated on the main circular regenerative strategies aimed at the recovery of the urban environment by integrating ecological, spatial and social dimensions.

2. Residues. From discarding to upcycling to reimagine cities as living organisms

At the 19th International Architecture Exhibition (Venice Biennale), the Circular Economy Manifesto sets bold targets for waste reduction and the promotion of material reuse. The Spanish Pavilion, curated by architects Roi Salgueiro Barrio and Manuel Bouzas Barcala, explores how architecture can contribute to the decarbonisation of the sector through an approach that goes beyond the model of environmental externalities, instead promoting "internalised" production practices that balance ecology and economics. «Nature produces no waste or externalities: every material flow

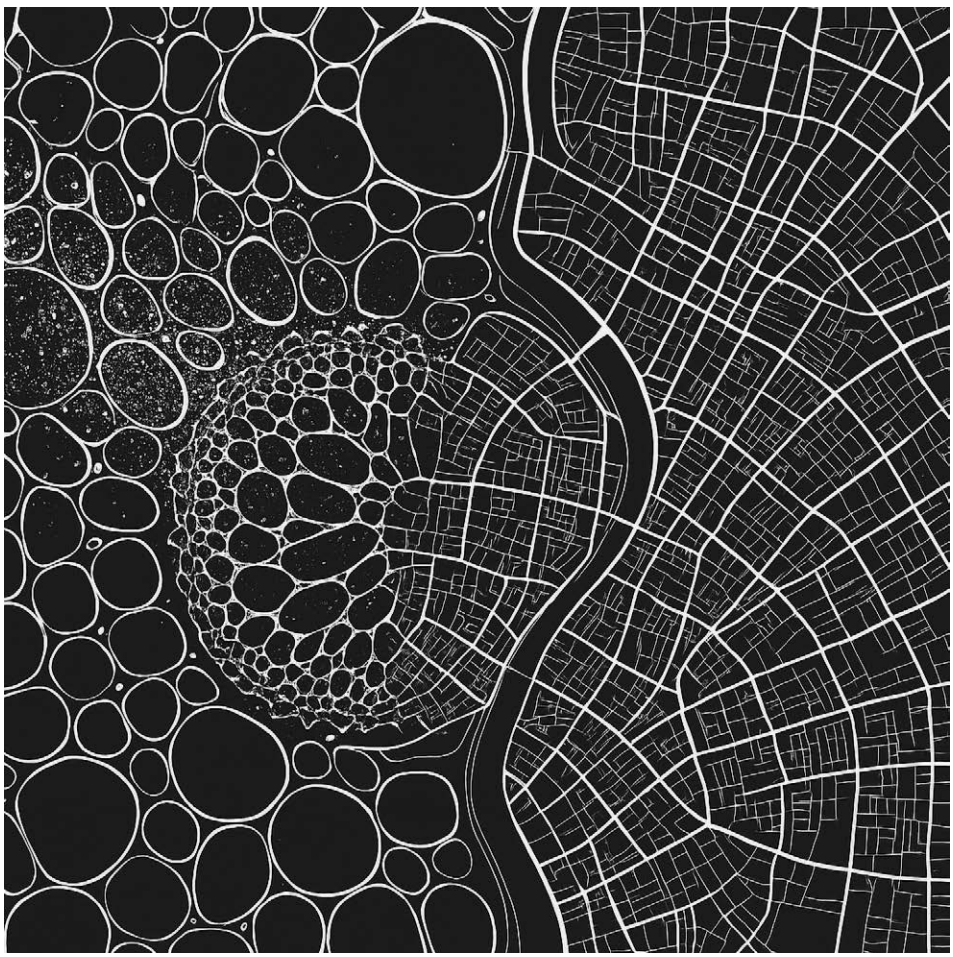

Fig. 1 – Cities as living organisms (Source: Author's elaboration).

is internalised in a continuous biological or technical cycle. What would happen if architecture followed this logic? How could we balance the economics of construction with the ecology of production? Every time we build a space, we deconstruct another, often in remote locations on the planet (MetaloCus n.d.).».

An ecological and low environmental impact approach to architectural and urban design must promote the enhancement of local production, sustainable land use and a balanced relationship between human settlements and natural systems. In this perspective, priority must be given to gradual and regenerative intervention strategies that avoid large-scale demolition and adopt an evolutionary rather than revolutionary approach.

The current construction system is one of the sectors that generates the most externalities: every time we build, extracting resources, consuming energy, marginalising local skills and producing pollution, we contribute to a profound imbalance between the buildings we construct and the territories we transform. Currently, the built environment is responsible for over 50% of the materials extracted in the EU, 40% of energy consumption, 40% of waste (EEA 2019) and 37% of greenhouse gas emissions (UNEP 2024b).

Until now, architecture has sought to respond through mitigation strategies, aiming to reduce the environmental impact of buildings. But this is no longer enough. The time has come to shift the focus from damage control to the urgent need to adapt.

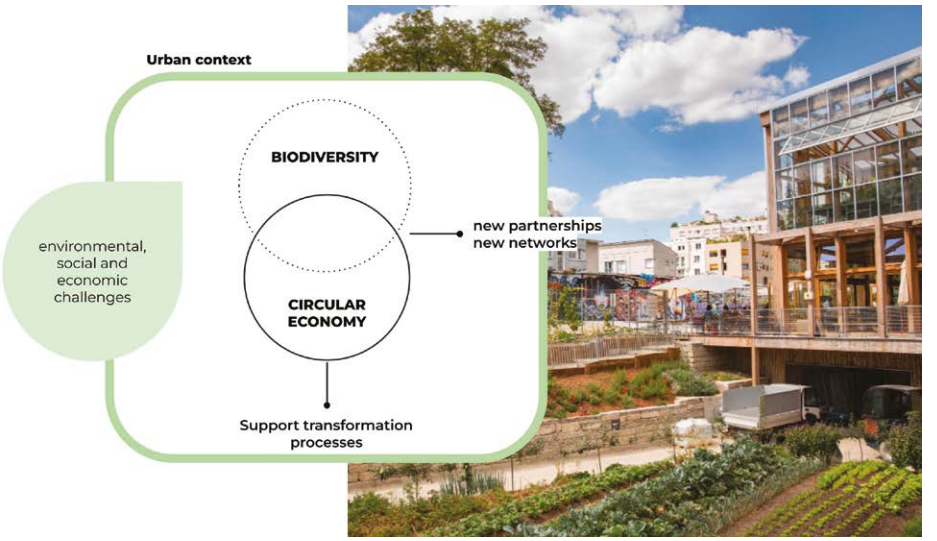

Fig. 2 – Operational research framework correlating aspects of biodiversity with those of circularity in urban transformation projects and processes (Source: Author's elaboration).

Adaptation means radically rethinking architectural design, imagining solutions capable of addressing the profound transformations already underway (Ratti C. 2025). Urban sites are complex, layered entities that are constantly evolving (Dovey 2010). Cities must therefore transform themselves over time in an adaptive manner, responding dynamically to contemporary environmental and social challenges (Geddes 1915).

In this context, there is a need to define guiding principles that integrate technological, environmental and systemic aspects into a circular and biodiverse vision capable of rebuilding the relationships between the natural environment, economic processes and urban and territorial transformations.

The project becomes a critical tool for rebalancing the internal relationships between ecologies and economies, intervening not only on the built environment, but also on design habits, supply chains and regulatory instruments, in order to build urban contexts that reduce waste production and maximise regeneration. The circular approach to resource management is one of the issues that the technological culture of architecture is called upon to address in order to overcome the linear approach to cities.

Current experiences promote the efficient use of resources, often managed within the urban perimeter, by recycling available materials or reusing building elements recovered from the context, considering the existing built environment as a source of supply. This contributes to "closing the loop", reversing the metabolic trend of urban areas from linear to circular (Ferrao and Fernández 2013).

3. Strategies for circular and regenerative technological and environmental design

Planning cities in the new Anthropocene, oriented towards circular metabolism, means accepting the challenge of an ecosystemic and networked approach, guided by an innovative vision but at the same time capable of recovering traditional knowledge and practices based on self-sufficiency and the conscious use of resources.

There are several approaches to circularity in architecture: these include the use of recycled products where possible, a focus on natural and local raw materials, adapting construction to the life cycles of components, and ensuring that component assemblies are reversible (McDonough and Braungart 2002; EMAF 2019).

Starting from the theoretical framework of the circular economy developed by the Ellen MacArthur Foundation (2012; 2017), which interprets urban systems as restorative and regenerative by intention and design, aimed at eliminating waste from production processes, regenerating degraded ecosystems and decoupling economic growth from the consumption of limited resources; the principles of circularity in the regeneration of critical urban areas derive from a screening of scientific literature and the analysis of demonstration and research projects at European level (Superuse studios, n.d.; Bauburo in situ, n.d.; Rotor, n.d.). Specifically, the processes that improve access to urban resources (Heisel et al. 2022) and make a concrete contribution to the recovery of the built environment and construction waste were examined in depth, interpreting the city as an urban stratification, an anthropogenic mine from which to draw on to promote infinite and regenerative production cycles. (Bender and Bilotta 2020).

The circular city can be understood as a complex and adaptive socio-ecological system, in which biophysical, social and institutional dimensions interact through circular flows of materials, energy and resources (Williams 2021). It integrates three fields of action: circular practices (recycling, reuse, recovery), regenerative interventions (restoration of ecosystems and ecosystem services) and adaptive processes (flexible design, co-creation, collective learning). This model is based on a transdisciplinary and multidimensional approach, capable of activating a structural relationship between the different spheres of sustainability — political, social, economic, ecological and territorial. This vision does not merely integrate these dimensions, but interconnects them in a unified framework, in which governance defines the rules, urban planning activates projects and evaluation guides and monitors processes. The interaction of these components supports the convergence between the economic (circular) dimension, the cultural and ecosophical dimension (generating a new urban metabolism) and the ecological dimension (fundamental to ensuring resilience). (Carta 2017)

The strategies that guide these models can be divided into five main areas that aim to achieve circularity in architecture and develop models inspired by ecological cycles and the regeneration of living systems.

4. Restoration of critical or abandoned buildings and infrastructure.

This strategy aims to avoid the intensive use of materials associated with the construction of new buildings by favouring the restoration and adaptive reuse of existing buildings. It promotes the continuity of value over time and space of existing building stock through construction measures that preserve and increase the value of buildings and infrastructure, such as maintenance, repair, and conversion, and significantly reduces emissions and resource consumption compared to demolition and new construction. (Stricker et al. 2022). This approach is integrated with the protection and enhancement of natural urban habitats by promoting land use that protects ecosystems, giving priority to construction on land that is already occupied or previously contaminated.

Adaptive reuse of building materials and components.

Don't throw anything away: work with what we have by promoting the reuse of waste from urban systems. Giving new life to existing materials or components available on site or from the urban mine is a key strategy in the circular regeneration process. Discarded building components embody the craftsmanship and design know-how that went into their creation; they therefore have an intrinsic value that goes beyond their simple value as scrap (Stricker E., et al. 2023). Identifying and utilising waste streams and mapping residual and reusable materials for reuse within projects is essential for keeping resources in the value chain. The built environment represents a resource of

materials for urban transformation, offering great opportunities for circularity. In this sense, the planning process is based on the availability of resources (Stricker et al. 2022).

Development of a long-term design process.

"The main architect is time," says Stewart Brand, founder of the Whole Earth Catalog (1968-1998). Extending the useful life of a building is essential to minimising overall resource consumption. Integrating circularity principles into the built environment encourages designers to adopt a flexible design process that responds to the needs and uncertainties of available materials and adapts to different future uses to ensure space-sharing models aimed at maximising the use of existing buildings. The use of the building thus begins to create metabolic relationships with the surrounding environment in response to changing needs and available resources (EMAF 2019). This strategy aims to reduce initial resource consumption by maximising the use of space and avoiding periods of disuse in the building programme.

At the same time, designing buildings and components so that they can be easily dismantled and reused in the next cycle is a fundamental step towards circularity. This approach involves the use of flexible systems that can be dismantled and rebuilt over and over again for different needs in different locations (Superuse Studios n.d.).

Inclusive and ethical governance for circular design.

Promoting a collaborative, multi-stakeholder approach that actively involves citizens, administrations, professionals and businesses, encouraging co-design and shared management of urban spaces, promotes circularity and biodiversity. Participatory processes strengthen social cohesion and ensure that territorial transformations respond to local needs, integrating ethical and cultural values that recognise nature as a non-human stakeholder and adopt circular processes (Buijs et al. 2016).

Ecological enhancement of the built environment

This strategy aims to introduce regenerative and nature-positive actions into the building design process. By focusing more on the ecological value of urban sites, measures can be taken to maximise the restoration of biodiversity in the built environment. The approach is based on closing material cycles, reducing environmental impact and restoring vitality to urban ecosystems, thereby improving residents' quality of life. Integrating natural infrastructure from the early stages of planning and design allows for more sustainable urban development, promoting virtuous relationships between the built environment, ecosystems and quality of life (EC 2021).

5. Prospects for the circular regeneration project

We already have everything we need: the point is not to continue producing, but to learn to read what exists more carefully, to recognise its latent value and reactivate it. The built environment is not an exhausted resource, but a reservoir of potential: every building, every material used retains a residual value that can be regenerated. From this perspective, urban materials and spaces should no longer be considered waste or scrap, but part of a new form of urban stratification, a veritable "anthropogenic mine" capable of feeding regenerative production cycles. Everything is in a process of constant transformation or reconversion - structures, cities, spaces, images, identities (Schwarz 1949). The adaptive reuse and regeneration of existing urban resources are the foundations of a new culture of urban renewal. Architecture, therefore, is no longer an act of replacement, but a process of transformation that favours reuse, regeneration and re-integration of materials in situ, while supporting the reactivation of local economies.

The transition to a circular model is not limited to the choice of materials, but requires a radical rethinking of processes, value metrics and decision-making models

(Stricker et al. 2023). It is about extending the useful life of cities and territories, reversing the extractive logic that has characterised contemporary urban development. In this sense, adaptive reuse and regeneration of existing resources are the foundations of a new culture of urban renewal, guided by the principles of "zero volume" and "no net land take". Unused or underused spaces represent strategic potential, capable of activating sustainable urban policies and stimulating participatory processes of active citizenship and proximity. However, isolated practices are not enough: a holistic and multi-scale approach is needed that recognises territorial metabolism as a key principle of planning, recomposing today's fragmented material flows and reconnecting industrial, natural and cultural systems. Urban regeneration programmes should be conceived as urban recycling districts, supported by territorial laboratories, multi-stakeholder alliances and collaborative tools capable of strengthening administrative effectiveness and enabling shared processes in terms of planning, economics and management.

In this context, circular thinking is an essential framework for urban and territorial strategies, guiding active, adaptive and responsive design processes that can integrate spaces into new cycles, accelerate their regeneration and connect sectoral cycles. The city can thus evolve from a consumer of land and resources to an integrated ecosystem, capable of self-regeneration and ensuring social, economic and ecological resilience. Only with recycling and biocentric urban planning, capable of combining technical, social and moral dimensions (Carta 2017), will it be possible to face the challenge of the Neoanthropocene (Sijmons 2014) and guide the transition towards systemic, equitable and transformative models of governance, capable of rethinking the city as a true laboratory of sustainability.

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