Ernesto Antonini, Jacopo Gaspari

Architectures for Next Generation EU Cities

Challenges, Key Drivers, and Research Trends

Ricerche di tecnologia dell'architettura
FrancoAngeli

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diretta da Giovanni Zannoni (Università di Ferrara)

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14. Design support tools for circularity-driven renovation projects

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Never demolish, never remove, or replace. Always add, transform, and reuse, is the leitmotiv of the 2021 Pritzker Prize Anne Lacaton and Jean-Paul Vassal. Rather, extend the lifecycle of buildings, make clever use of what exists, enhance their performance, and prepare them to face future challenges. In this sense, building renovation is the most sustainable and circular kind of intervention that can be undertaken in the built environment.

However, simply reusing existing buildings is no longer enough by itself. As circularity gained traction in many sectors, also in construction, key players have been called to perform sustainable renovation projects in the long term. This means considering the impact from the entire life cycle of added materials and components rather than only focusing on lowering the operational energy of existing buildings. Otherwise, the final energy and carbon balance of the renovation might be unfair.

Given the high degree of complexity of the retrofitting process, which includes environmental, social, logistical, technical, and economic issues, designers would benefit from a comprehensive assessment of as built and an effective forecast of the effects of design choices on the building and its broader context.

To this end, several design-supports tools have been developed, the most promising and forward-looking, including sustainability and circularity of resources as guiding principles.

14.1. Building renovation as circular action

In 2018 Constructions accounted globally for about 36% of final energy use and 39% of carbon emissions (GlobalABC/IEA/UNEP, 2020). This was mainly due to the operational stage of buildings, which is related to space and water heating, cooking, cooling, and lighting systems. However, it is estimated that about 11% of the global sector's carbon emissions are due to embodied carbon, which are emissions related to the whole life cycle of buildings' materials and components. Furthermore, the sector is accounted for over 50% of all extract materials and 40% of materials sent to landfills yearly. Even if new buildings are increasingly aiming for net zero carbon, zero energy or even positive energy, they are few in comparison to the existing stock. Therefore, because buildings have a long lifespan and a considerable part of the overall building stock in developed countries will still exist in 2050, it follows that the construction industry must address climate change and resource depletion mostly by enhancing what is already in place (McKinsey & Company, 2009; Lucon et al., 2014).

In this context, renovation emerges as a key strategy as contributing to both reducing energy demand from existing buildings and boosting the circularity of resources (Gobbo, 2021; Preservation Green Lab, 2011). The first relates to enhancing energy performances of already existing buildings, thus reducing their operational energy up to 75% (Lucon et al., 2014). This entails, for instance, insulating envelopes and upgrading systems to limit unwanted heat exchanges, either out- or inwards. The latter relates with reusing buildings and structures, so reducing the amount of new materials to add, or at least recycling materials, and construction and demolition waste (Campioli et al., 2018). This would prevent new resources from being extracted, processed, and moved, thus new environmental impacts from being generated. Not to mention that reuse instead of demolition and reconstruction entail benefits other than environmental: if any, it allows to retain cultural values of the building, the sense of place, as well as memories and personal associations of inhabitants and local communities. For these reasons, in order to reach the ambitious energy and carbon saving targets set worldwide, policymakers are supporting the massive and effective renovation of existing assets. In Europe [EU] the Renovation Wave is the main strategy to this end (COM (2020) 662 final). Launched by the European Commission in 2019 under the wide umbrella of the EU Green Deal, the strategy is grounded on the fact that more than 220 million buildings in Europe date back before 2001 and are highly energy demanding. For instance, in the southwestern EU average energy demand for heating is 100-200 kWh/m^{2}y, compared to the standard for new efficient buildings, around 15 kWh/m^2y (Harvey, 2013). Older buildings are much less efficient at retaining warmth, and as a result, more than 75% of the EU's building stock leaks significant energy (BPIE, 2011; IEA, 2020). To address this issue, the EU aims to support energy renovation for around 35 million buildings by 2030, by means of significant incentives and investments, in addition to encouraging national governments, private investors, architects, designers, and local communities to get involved. In this context, however, renovation is no longer related with energy efficiency only. It should now be reframed according to the concept of circularity, as the sustainable use of natural resources, reduction of waste and measurement of resource efficiency has also become essential challenges, especially in times of dependence on supply. So, as a forerunner, the EU has launched a new Circular Economy Action Plan in 2020, where a specific Strategy for a Sustainably Built Environment is planned to be included soon (COM 2020 - 98 final). This Strategy will promote circularity principles in the built environment by:

- supporting recycled materials through a new Construction Product Regulation;
- promoting measures to improve the durability and adaptability of built assets, such as the use of construction digital logbooks;
- using the EU framework Level(s) to integrate life cycle assessment in public procurement as a pilot action;
- considering a revision of material recovery targets set in EU legislation for construction and demolition waste and its material-specific fractions;
- promoting initiatives to reduce soil sealing, and rehabilitate abandoned or contaminated brownfields.

14.2. Circular principles in renovation projects

This vision that integrates circular principles into renovation strategies is quite recent in the sector. For several decades indeed, "green buildings" were thought to be enough to cope with the environmental crisis. Policymakers, designers, and clients themselves have focused on reducing building's operational energy alone until it was pointed out that it was not enough to lessen the sector's environmental impact (Pomponi and Moncaster, 2017). Refurbishment does not always produce positive environmental balances because the potential loss of matter and embodied energy in the dismantled elements and the lack of control of the environmental quality of added materials and components risk producing an impact greater than demolition and new construction (Munarim and Ghisi, 2016; Berg and Fuglseth, 2018).

So far, indeed, plenty of thermal insulation panels have been installed thinking at conductivity index only, as well as thousands of photovoltaic panels have been set up considering only peak kilowatts for the first years. What will happen now that the first installations are approaching the end of their expected lifespan? Will these be simply disposed and replaced with most performing ones? Or do they have a residual value that deserves to be exploited further?

All stakeholders from the building sector are encouraged to reflect on this, on what happens beyond construction or renovation works. Even if there are no universal responses, the promising trajectory is to enlarge the perspective and go beyond the local and short-term effects of constructions.

A circular built environment should have fewer virgin resources, and most new building materials are reused, salvaged, biobased, or recycled; buildings are meant to be restored and upgraded rather than demolished, and they are used more intensively (by more people utilising more services), and lastly, when buildings reach the end of their useful life, as much material as possible is salvaged and recycled (USGBC, 2019).

Some useful principles can be implemented to this end, above all the 3R principles that are also supported by the EU Green Deal (COM 2019 - 640 final). This is, in the preferable order: reduce, reuse, and recycle. This translates into operative strategies and procedures that are developing at all levels and stages in the construction chain, from site to building materials, from the production of components to the demolition stage.

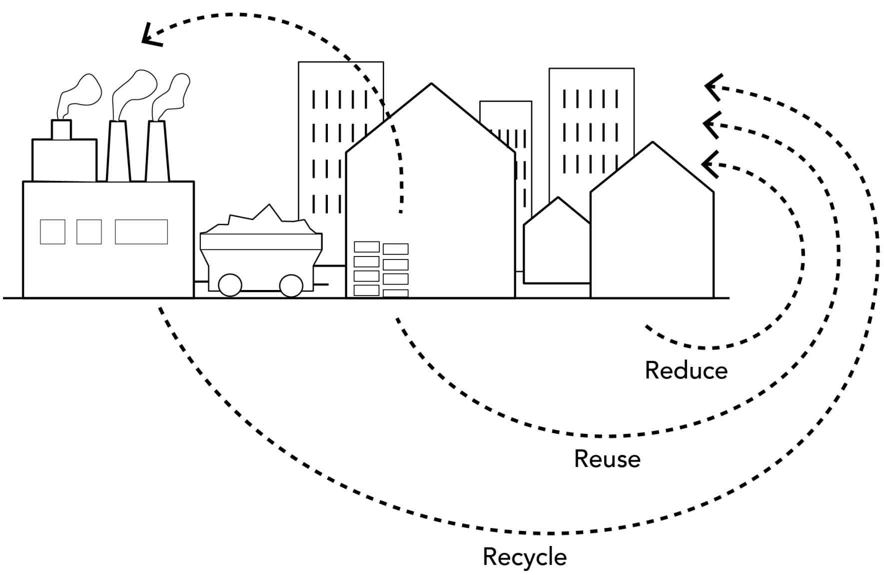
Reduce the amount of waste you produce. It deals with the idea of extending as much as possible the service life of buildings and materials to exploit their embodied energy, reduce the use of primary resources and the production of construction and demolition waste.

Therefore, it is important to implement effective and speedy procedures to assess the residual value of buildings, components and materials and their suitability for retrofitting (Scolaro and Marchi, 2019), as well as upgrading systems whenever possible.

Reuse items as much as you can. That means implementing effective strategies to use available materials and components on-site or in other buildings. Innovative trends in this field are platforms and experiences related to the Urban Mining concept, which extends landfill mining to the process of reclaiming compounds and elements from any kind of anthropogenic stocks, including buildings (Cossu and Williams, 2015). Noteworthy to this end is the Harvest map, an open-source platform whose aim is to exploit the end-of-life materials and sustain new construction, in line with the principles of small-scale circular economy (*Harvest Map* website; Jongert et al., 2007)

Recycle items wherever possible. Great effort has been put into implementing a recycling production chain for the construction sector, even in cooperation with other industries (Neves et al., 2020). This mainly deals with the industrial symbiosis practice that was firstly implemented in Kalundborg in Denmark (1972) and consists of resource sharing and waste valorisation among different supply chains to limit environmental impacts and encourage the economic decoupling of the production sector.

Fig. 14.1 – Circular principles in renovating the built environment.



Source: Elaborated by the author and Licia Felicioni.

These 3R principles must comply with the overall effort of reducing energy demand and carbon emissions for the entire construction chain (sustainable principles) (USGBC, 2014). Thus, preferring low-impact materials, such as local materials with short transportation tracks, or natural ones with low energy needed for extraction and processing, or materials that are designed to last (i.e., durable).

Lastly, another concept tightly related with circularity is gaining traction in the built environment, namely resilience. In fact, building codes and regulations often target occupants' safety, which is obviously of utmost importance, but do not care about the ability of a building to quickly recover damages to the building structure, systems, and components in the event of an earthquake or environmental catastrophe (resilient attitude) (ARUP, 2014). As a result, buildings' repair and restoration might be time-consuming, costly and in general terms, not convenient. Resilience-driven approaches are instead leading to a new vision of the building itself, which should be designed to last and adapt to new natural or human events.

It is thus important to consider prolonging the lifecycle of constructions to be resilient, sustainable, and circular, assuming both a short and medium-to-long term perspective. To sum up, operative strategies deal with maintaining as much material as possible, limiting integrations and replacements, recycling the dismantled building components, and choosing materials according to their environmental profile and their durability.

14.3. Implementing circular thinking in renovation projects

Although the economic and technical feasibility of building rehabilitation has been largely proven, as well as potential societal and environmental benefits, renovation rates remain low (Artola et al., 2016). Not to mention the application of circular principles.

In fact, building owners and potential investors face several obstacles in renovating their buildings. Along with difficulty in accessing funding – which has been partially covered by exceptional incentives in the last years (e.g., Super bonus in Italy), one of the most frequently mentioned barriers is the lack of information about where to begin and how to make the right steps (Fabbri et al., 2016).

On the one hand, technical interventions to renovate existing buildings are quite well established. Energy retrofit is mainly based on envelope thermal insulation; windows replacement; systems upgrading and integration with additional ones based on renewable energy sources; installation of shading systems for glazing. Adaptation of buildings to different users' needs or new functions is mostly achieved by means of cost-effective, reversible, and flexible systems, like dry wall for internal partitions, installation of self-bearing structures for elevators, emergency stairs, and additional lodges.

On the other, a coherent approach capable of making specific interventions working together is lacking. In addition, considerations about environmental implications are difficult to embed in the process and be understood by clients.

Fig. 14.2 – Find the differences: the typical transformation of multi-family buildings in less than 50 years. More than ten differences emerge clearly, such as the glazing closing loggias, and many more have been performed inside.

Source: Elaborated by the author and Ambra Lombardi, based on ACER Archive.

Refurbishment is indeed featured by a high degree of complexity that depends on the specific features of the building and its transformation during decades.

In general terms, major issues can be grouped in the following categories:

- *Technical issues*, which relate with the difficulty of collecting suitable data on construction features, assessing residual performances of structures and components, and evaluating compatibility between new and old materials.
- *Logistic issues*, which mainly relate to the interference of the renovation project with occupancy of the building, both in terms of time of the intervention and its intensity (whether occupants can stay in or not during operations). This, for example, may drive owners who have no other options to relocate for small upgrades based solely on outside insulation and not well-performed windows replacement. In addition, existing components might be difficult to be moved elsewhere.
- *Socioeconomic issues*, which for instance, pertain the investment capacity of the owner, or the type of ownership of the building. Renovation of multi-property buildings can be particularly challenging as it is difficult to find agreement among several owners with different spending capacities, needs, and time constraints, so affecting materials and design choices.

This is just to mention a few conflicts that might occur in a renovation project and add complexity to the process itself. But there are many others indeed, some of which are already known, while others will occur in the future according to upcoming challenges for the environment and society.

What emerges is that the renovation project deals with several complex topics different in nature and scale and that, even more than in new constructions, need to be carefully considered in relation with the specific context in which one is operating. It is a difficult task for designers to adapt buildings built in a different sociocultural context to new challenges and needs while, equally important, giving them the degree of flexibility that will ensure their suitability for many years to come, most likely facing new, unanticipated, and uncertain challenges.

14.3.1. Complexity and multicriteria assessment

The complexity that a design team should manage to perform an effective, circular, future-proof renovation project has clearly emerged. It derives that despite the extensive knowledge of technologies and interventions that can be implemented to renovate, retrofit, refurbish an existing building, designers alone often fail to consider all the issues properly. They would rather benefit from a design-support tool to manage all the interrelated topics.

Figure 14.3 conceptualizes the problem, from the knowledge of technical intervention to the need for structured and effective design support tools.

Fig. 14.3 – Conceptualization of the problem, from technical intervention, and procedural gaps to assessment and predictive tools.

Source: Elaborated by the author and Licia Felicioni.

Today designers can benefit from the guidance of several tools developed to this end. Most of them are based on multi-criteria analysis, that is, investigating different topics in a coherent manner by means of the same tool. Even if this operation might raise some concerns, especially related with the fact of combining "apples and oranges" (Jesinghaus, 2000), many of these tools are very helpful and well-established.

These generally evaluate different aspects of the project through specific indicators ranging from site condition to water management, from energy performances to waste management. Starting from the structured, guided assessment of "as built" in order to get a quick but comprehensive picture of the starting point, the design team is then guided to select the most effective design strategies to reach overall the best possible configuration for the object, that is "the best compromise" (Marchi et al., 2021). For this reason, the implementation process is often iterative. Assessment and simulation of the project's effects are thus recognized as keys to a successful intervention.

14.3.2. Green Building Rating Systems for sustainable and circular design

Green Building Rating Systems (GBRSs) are probably among the most famous and valuable multi-criteria tools to assess and guide the whole design process to be greener. These tools support the consistent evaluation of a vast range of green building requirements, among which low energy consumption, efficient water management, good indoor environmental quality, sustainable location, and use of natural materials. The relative performances of the object (whether it is a new construction or an existing building) are weighted using a balancing process specific to each GBRSs and are combined into a single score/judgment that shortly communicates the building's overall level of sustainability. In this, they are useful not only in supporting the design team to evaluate all the relevant aspects of the building together, but also in guiding them to map important synergies among the building elements and function, hence enhancing the overall performance of the project.

Among the most spread worldwide: *Leadership in Energy and Environmental Design* (LEED, U.S.A.), *British Building Research Establishment Environmental Assessment Method* (BREEAM, UK), *Deutsche Gesellschaft für Nachhaltiges Bauen - DGNB System* (abbreviation in German for the German Sustainable Building Council) (*BREEAM* website; *DGNB System Version 2020 International* website; *LEED* website; Say & Wood, 2008). Noteworthy is also the *SB Method* and its national applications, such as *Verde* (ES), *SBTool PT* (PT), *SBTool CZ* (CZ) and *Protocollo ITACA* (IT) (*iiSBE Italia* website).

Many of these protocols embed circular thinking principles in the evaluation. For instance, they include credits that reward project teams who support the rehabilitation of brownfields, and minimize and optimize the use of buildings, building products and materials throughout the project life cycle, from construction and demolition waste management planning to product selection and ongoing sustainable purchasing. The most common tool to measure how materials and resources are used by the team is Life Cycle Assessment, but often speedy methods are provided in credits' specifications.

Moreover, several GBRSs have schemes dedicated or adaptable to renovation projects, which means that specific credits for the evaluation of existing building constraints and features are included. These generally have the same structure of new construction, but few credits are applied, as well as less strict gauges. Table 14.1 illustrates schemes dedicated to renovation in two of the most diffused GBRSs worldwide, as well as specific credits related with resource circularity.

Tab. 14.1 – GBRSs, renovation and resource circularity.

LEED (USGBC, 2019)
Schemes for renovation • New Construction and Major Renovation • Operations & Maintenance • Core & Shell
Credits for circularity • High Priority Site and Equitable Development (LT) • Outdoor and Indoor Water Use Reduction (WE) • Enhanced Commissioning (EA) • Optimize Energy Performance (EA) • Building Life-Cycle Impact Reduction (MR) • Environmental Product Declarations (MR) • Sourcing of Raw Materials (MR) • Material Ingredients (MR) • Design for Flexibility (MR) • Construction and Demolition Waste Management (MR)
BREEAM (BREEAM, 2021)
Schemes for renovation • Refurbishment • Fit Out • Water Sub-metering; Leak detection; Leak prevention; Efficient

Credits for circularity

- Building LCA (Mat 01)
- Sustainable procurement (Mat 03)
- Designing for durability & resilience (Mat 05)
- Materials efficiency (Mat 06)
- Recycled aggregates / Recycled and sustainable aggregates (Wst
- Life cycle cost and service life planning (Man 02)
- Monitoring of construction site impacts (Man 03)
- Reduction of operational energy use (Ene 01)
- Energy Sub-metering (Ene 03)
- Water Sub-metering and Efficient equipment (Wat 02)
- Construc. resource efficiency and Diversion from landfill (Wst 01)
- Recycled and sustainable aggregates (Wst 02)
- Adaptability (Wst 06)

14.4. Positive trends and prospects

Assessment and design-support tools that have been developed so far certainly have limitations. As much as they are “multi-criteria”, some aspects are neglected in favour of simplicity and user-friendliness. Their scope is indeed to make a complex problem easier to grasp.

However, in the last few years, big steps forward have been made to fill these gaps. Green Building Councils worldwide have tried to make GBRSs more comprehensive and balanced: the introduction of circular thinking and Life Cycle Assessment tools are certainly among the most relevant innovations in this regard. Furthermore, there is such a multitude of these tools that designers and clients might be confused. Some unifying tentative is now approaching, such as Level(s) by the European Union consisting of a transparent and robust framework of indicators that can be used by policymakers and stakeholders across the EU, and intended to be included in GBRSs (Cordero et al., 2019). Level(s) as well includes several circularity measures to boost effective and sustainable renovations.

Despite the differences in available tools and methods, what is interesting to note is that great effort is being spent in many fields to support designers and other relevant actors to renovate the built stock in a holistic, sustainable, resilient, and cost-effective way. Therefore, social, environmental, and economic measures are increasingly embedded and integrated into design-support tools, aiming at a better future.

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Cities are facing unprecedented challenges driven by different forces. On the one hand the ever-increasing effects of climate change are impacting on the urban microclimate and environmental balance, on the other one social, political and economic issues are influencing the living conditions, the accessibility to primary services and resources, as well as growth opportunities for the younger generations.

The rise of a social awareness regarding these topics suggests how relevant scientific-based evidence could be and calls for additional efforts to bridge the gap between science and society, in order to stimulate a collective responsibility and due actions.

The complex interaction among these factors inspired a forward-looking reflection not only on key drivers of change but also on possible future trends for research assuming an interdisciplinary and multiscale perspective. The book collects several experiences from different contributors working in many contexts and countries, but sharing the same projection to the future. Four key priorities are addressed: the resilience to climate-related events and impacts, the energy issue with reference to both the advances at building level and the role of end users, the capacity to adapting components and systems to emerging needs, and the adoption of assessment and simulation tools for improving the design capacity within a circular system perspective.

The book provides therefore insights, experiences, approaches to deal with current and especially with future transition processes which are expected to shape the cities of tomorrow. Thus, its ambition is not to provide definitive answers but to become a starting point for exploring promising research pathways for the next generation cities.

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