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Design Strategies for Circularity: Km0 Architecture in the Spanish Mediterranean

Abstract

Purpose:

City planning and construction have embraced circular economy principles, converting them into various indicators. Particularly in the European context, the question '*what architecture for circularity?'* is answered with policies focusing on techniques, materials, and disassembling construction. This paper analyzes a new approach to sustainable design and explores the concept of Km0 architecture. The objective is to demonstrate the design strategies of a contemporary architecture based on local resources and knowledge, an architecture that works with the shortest possible loop in circularity, i.e., with the cycle that consumes the least amount of energy.

Design/methodology/approach:

The paper presents two ways of understanding sustainability in architecture: the first as a result of policies and the second associated with the design and innovative-based New European Bauhaus initiative. Within the scope of this last understanding, we analyze three cases on the Spanish Mediterranean coast that have recently received media attention and prominence. The selection responds to a specific climate adaption through a certain typological and functional diversity of the works.

Findings: The studied cases exhibit a more equitable and cost-effective circularity based on the time factor, have long life cycle designs, and serve as repositories of cultural identity. Km0 architecture reduces emissions using local resources and mitigates environmental conditions by combining traditional and modern design strategies.

Originality/value: This paper fulfills an identified need to study local understandings of the built environment that would ensure a more fair and inclusive European green transformation.

Keywords

Circular Architecture; Km0 Architecture; New European Bauhaus; Architectural Design; Sustainability

1. Introduction

Building construction concentrates enormous amounts of energy through the use of available resources. This was well known to the eighth-century Muslims who built the original mosque of Cordoba over a Visigothic basilica from the mid-sixth century, who then successively enlarged it in the ninth and tenth centuries, reproducing the same spatial layout; to the Christians who in the twelfth century reused the Islamic temple for Catholic worship, and those who finally superimposed a Gothic cathedral over it in the fifteenth century (Moneo, 1985). Measured in terms of environmental impact, building construction represents 36% of global energy consumption and is responsible for 40% of current emissions (Schenk, 2022). Without any knowledge of the *Life Cycle Energy Consumption of Buildings* (Azari, 2019), our ancestors were already aware of the need to minimize energy costs, through the reuse of what is built (embodied energy) and the maximum extension of the useful life of an efficient building (operational energy).

The principles of the circular economy promote Reduction, Reuse and Recycling (the 3R's) with the intention of tracing loops rather than describing linear consumption trajectories with their respective environmental footprint. The translation of these concepts to architecture is determining the design of buildings that aspire to obtain sustainability certifications such as LEED or BREEAM and to improve in indicators such as the Material Circularity Indicator (MCI), the Material Reutilization Score (MRS) and the Building Circularity Indicators (BCI). However, the same European institutions that have been dictating circularity policies since 2015 seem to have recently changed course, or at least blazed another trail. The New European Bauhaus (NEB) initiative aspires to become a new way of understanding sustainability, inspired by comprehensive, inclusive and innovative designs. Its approach is also different: as opposed to the traditional top-down policies in which express regulations must be followed, in the NEB the discursive corpus is developed through bottom-up activities, making it possible to tap into the diversity of cultural identities.

This paper analyzes these two approaches to sustainable design and explores Km0 architecture, which is committed to extending the life cycle of buildings before implementing the R's framework. The objective is to demonstrate the design strategies of a contemporary architecture based on local resources and knowledge, an architecture that works with the shortest possible loop in circularity, i.e. with the cycle that consumes the least amount of energy.

2. Theoretical background

2.1. From Circular Economy to Circular Architecture

The conceptual roots of the Circular Economy (CE) date back to the end of the last century and have their origin in environmental economics and industrial ecology. The different theoretical routes emerge from the principles of the 3R's –Reduce, Reuse and Recycle– developed in the first decade of the 21st century and focused, fundamentally, on production modes and waste management. The first models that were developed differed from country to country and continent to continent: while in China the CE has always been a political objective, in Europe and the USA the first approaches emerged from bottom-up processes (Ghisellini *et al.,* 2016).

In December 2015, the European Commission adopted the first Circular Economy Action Plan, whose implementation in fifty-four concrete actions was due to be finalized in 2019 (EC, 2015; EC, 2019a). These focused on issues as wide-ranging as Production, Waste Management, Market for Secondary Raw Materials, including particularities on Plastic, Construction and Demolition, and Biomass and bio-based materials (EC, 2019b). Since then, EU countries have produced a multitude of reports, and research on the definition and scope of circularity has grown exponentially (Kirchherr *et al.*, 2017; Kalmykova *et al*., 2018).

The initial framework of the 3R's has evolved over the last decade and the most recent studies point to a nine-stage categorization that defines, at the same time, the extent of the loop. And so, the list of principles: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover, starts with high levels of circularity and moves down to those that need more energy to extend their useful life. The first three terms –Refuse, Rethink and Reduce– correspond with the shortest loop, or high circularity, as they suppose a smart use of materials and eliminate the waste at the design stage. At the opposite extreme, Recycle and Recover are associated with the lowest levels of circularity, or longest loops, as they involve additional energy use to maintain their usefulness. The intermediate terms Reuse, Repair, Refurbish, Remanufacture and Repurpose refer to the operations for lifetime extension (Potting *et al.*, 2017).

Speaking of circularity in urban planning or architecture generally transfers the principles of the CE to the urban or building context. As such, a circular city is one "that practices circular economy principles to close resource loops, in partnership with the city's stakeholders (citizens, community, business and knowledge stakeholders), to realize its vision of a future-proof city" (Prendeville *et al.,* 2018, p. 187) and which also faces up to challenges of city-level system boundaries related to food, buildings, mobility and nature (Paiho *et al.*, 2020).

The indicators come into play as the application of circularity becomes more specific, becoming necessary tools for measurement and comparison (van Stijn and Gruis, 2020). The circular city is then broken down into specific indicators for the various key sectors (waste, energy, water, green, buildings and mobility) and dimensional indicators relating to cross-cutting issues (environment, social, cultural) (Paoli *et al.*, 2022). As is the case in the city, the identification of criteria and indicators for circular building is in demand (Attia, 2021). The spotlight is more on construction systems, envelope technologies, and building materials than on spatial design, probably due to the requirements demanded by the environmental standards and certifications of the companies and organizations in the sector.

2.2. Circular Architecture as a Result of Policies

At present, two types of documentary sources define what CE is in architecture. On the one hand, government institutions with their own laws and standards and, on the other, the various bodies that issue *beyond the code* seals and certifications. These documents are of vital importance for professional practice because they substantially shape architectural production. In one way or another, architects consider these requirements at different stages of the project development.

In the field of European standards, the common approach to assess and report on the sustainability of buildings is called “Level(s)” (EC, 2020). Officially launched after the European Green Deal initiative and the following “Circular Economy Action Plan,” the website includes a wide variety of guidelines aimed at architects, property developers, manufacturers, and public authorities with the aim of putting circularity into practice. Over the years, “Level(s)” has become a framework based on a number of indicators that refer to three sequential stages of a building project: Level 1 is for conceptual design; Level 2, for detailed design and construction and Level 3 for as-built and in-use performance. While the last two levels require quantitative assessments, the first aims to be qualitative (EC, 2021b). Finally, as of June 2022, “Level(s)” offers its own *Calculation and Assessment Tool* which functions as a checklist for qualitative indicators, and requires calculations in specific software for quantitative indicators.

Regardless of these initiatives, the different member nations are developing their own legislation and regulations. The most recent analyses of the existing literature show a fragmented panorama of criteria conducive to circularity in construction. The most repeated strategies are assembly/disassembly capacity, the choice of renewable and recyclable materials, adaptable and flexible design, and prefabrication. The European countries with the most advanced codes are Denmark, Netherlands, Finland, Germany, Sweden, Spain and Italy (Eberhardt *et al*., 2022).

As regards seals and certifications, the most widespread and best-known sustainability rating systems in the built environment are the Leadership in Energy and Environmental Design (LEED®) Certification from the US Green Building Council and the Building Research Establishment Environmental Assessment Method certificate (BREEAM®) from the Building Research Establishment (Cole, 2013). In both cases, the emphasis is on evaluating the building in terms of energy (efficiency, CO2 emissions, lighting, renewable energy production, etc.), water management (reduction and reuse), indoor environmental quality, and location and transportation (Awadh, 2017).

As a result of these guidelines, some types of architecture, depicted in the publications of institutions and organizations, focus more on construction issues than on the design itself, and demonstrate a high level of cost-intensive technology to achieve optimum energy efficiency. This is the case of the works analyzed by Metabolic in the publication “The Circular Design of Buildings,” referenced on the EC website (Metabolic, 2022). Neither the principles adopted for the circular design, nor the buildings shown are based on a local context or building tradition. In fact, it could be said, they fundamentally think about *the day after*, prioritizing disassembly over permanence.

2.3. Towards a New Concept of Sustainability

In January 2021, the EC launched the New European Bauhaus (NEB) initiative. Defined as “an environmental, economic and cultural project, aiming to combine design, sustainability, accessibility, affordability and investment in order to help deliver the European Green Deal” (EC, 2021a), the NEB is proposed as a new element to highlight aesthetics, the will to build a bridge between the world of art and culture and the world of science and technology, and the insistence on inclusion and social cohesion.

The news had an impact on the field of architecture, both in professional associations and in higher education. At the time, many schools of architecture were still teaching via online methods as a result of the pandemic situation, so work on social resilience and the environmental impact of the events was very much in evidence (Mahima *et al*., 2022). Only four months later, the first NEB Awards were published. The first competition strand, *NEB Awards*, was about existing projects, while the second was devoted to concepts or ideas submitted by participants under 30, *NEB Rising Stars*. The ten categories of the awards addressed general topics, such as “techniques, materials and processes for construction and design” and “building in a spirit of circularity”. Very specific topics on “rurality and nature-based solutions” were also included, and cultural, social and educational aspects were not neglected (“reinvented places to meet and share”, “interdisciplinary education models”, “modular, adaptable and mobile housing for temporary”, “emergency needs”). Of the twenty prizes awarded, fifteen went to proposals from Mediterranean countries, all of them with a strong social and local component (EC, 2021c).

The 2022 call for awards reduced the number of categories to four (“reconnecting with nature, regaining a sense of belonging”, “prioritizing the places and people that need it the most”, “shaping a circular industrial ecosystem” and “supporting life-cycle thinking”) and was once again dominated by proposals from the Mediterranean region. The call for the 2023 awards was open until January 31 and, while retaining the same categories, added a new strand for educational projects. The NEB has also launched other calls with significant financial resources to support lighthouse demonstrators, linked to projects on urban innovation and cities and local initiatives aimed at cities and citizens. All of them are designed to put into practice the values pursued by the European initiative.

In parallel, the NEB also operates on a clearly bottom-up basis; after the launch, European groups of very different orientations and scales have spontaneously created discussion groups. While some of these groups have been connected to government institutions, others have simply been social movements inspired by an integrative vision of the three pillars of sustainability (environmental, social and economic). This collaborative effect caused by the launch of the NEB has been used by the EC to raise the so-called NEB Labs, thus recognizing the work of some groups as “a ‘think and do’ tank to make the New European Bauhaus a reality through concrete and tangible projects’ and as ‘incubators to connect people and learn from one another's experiences” (EC, 2022). Such is the case of the lab NEB goes South, which integrates representatives of six schools of architecture in southern Europe, which acknowledge their common geographical and cultural legacy, and strengthen their ability to develop social and nature-based solutions together (University of Porto, 2021).

3. Design Strategies for a Km0 Architecture

In the same way that the Km0 philosophy appeared in our food consumption, Km0 architecture is presented as an opportunity to reformulate the definition of space from proximity resources. In the field of gastronomy, the consumption of market produce reduces the carbon emissions associated with its transportation, strengthens the local economy, and helps to preserve the know-how of local cuisine without losing the opportunity to innovate. Similarly, when materials, construction techniques, and designs are integrally combined in the solutions offered by the nearby environment, they achieve greater sustainability. These constructions have lower emissions, take advantage of the knowledge of vernacular architecture and have an economic impact on their location.

Architecture with proximity design strategies has played an important role in Spain in recent years, if we look at the prizes awarded annually by architects' associations (local and national) and the publications in architectural magazines. An approximate census of these two collections of data would yield some 50 projects of various scales and functional programmes in the last 10 years. Out of these, we analyze below three examples of architectures with proximity design strategies. Their selection responds to two criteria. The first is the geographical distribution of the Spanish Mediterranean coast –Barcelona, Valencia and Palma de Mallorca– as they share features related to adaptation to the climate. The second is the typological and functional diversity of the projects in consolidated, peripheral or peri-urban fabrics –adaptive reuse of an existing facility, new educational facilities, and social housing for public development– (Figures 1, 2 and 3). With these combined parameters, we aim to present a meaningful representation of those architectural projects that have received the most media attention and prominence. Other examples could be included in this sample, but the ones chosen have sufficient graphic and planimetric documentation to be analyzed with the same parameters and to be able to establish the consequent parallels.

3.1. HArquitectes, Cristalería Planells Civic Centre, Barcelona, 2017

The project is the result of a public competition launched by the municipal government of Barcelona. The project proposes to intervene in an industrial building that previously contained a glassworks, which must preserve the facades on two of the three sides of a plot of land with a pronounced triangular geometry. The project strategy adopted by the winning studio, HArquitectes, is to use the protected walls as an envelope and separate the new building, thus creating covered side courtyards. The new building is organized in two longitudinal strips with a linear circulation space, so that, through its cross-section, it is possible to understand the functioning of its air control and management under natural conditions (Figure 4).

The energy model is based on three elements: the courtyards that act as climatic spaces for the pre-treatment of ventilation air, the thick masonry walls that provide the building with thermal inertia, and the large solar chimneys with the Venturi effect sunshades on the roof. During its use in the cold months, the building tends to be closed off to the outside, avoiding heat losses accumulated in the mass of its structure. In addition, a geothermal heat pump system, reinforced by an aerothermal pump, provides underfloor heating for the classrooms. In contrast, during the summer, the building is ventilated as much as possible to cool the elements and make the most of its thermal inertia, so the chimneys work at their maximum capacity. The air conditioning uses an underfloor cooling system and, although there is no artificial air conditioning, the air is circulated in a controlled and intentional way, which means that the building is necessarily automated (Tectónica, 2019).

The result is an extremely efficient building complex that has a LEED gold rating and provides honest and transparent evidence of its entire operation (Figure 5). According to its designers, the materiality is based on structural reasons –the achievement of thermal inertia– that enhance the value of the brickwork, “integrating it and not singling it out,” “using it and not making it sacred” (HArquitectes, 2019). For all these reasons, the project has garnered national and international recognition both in the field of heritage rehabilitation and efficient construction.

3.2. Gradolí & Sanz arquitectes, Imagine Montessori School, Valencia, 2019

This private school, located on a plot of land bordering a town near Valencia, exploits the potentiality of its natural location, not only in accordance with the pedagogy taught, but also as a design strategy. The complex is organically integrated with the surrounding pine forest through the sequential alignment of similar elements –the classrooms– that are arranged along the course of the adjacent ravine (Figure 6). This lively but modulated design allows for phased construction. As for the design of the classrooms, they incorporate resources that are very commonplace in Mediterranean architecture to optimize ventilation and lighting: cross ventilation, the arrangement of a deep porch that casts shade and allows an extension of the interior boundary to the outside, and a conveniently oriented skylight that captures the sun and introduces indirect natural lighting in the center of the teaching space (Figure 7).

The construction uses local materials and techniques. The structure is made of perforated brick load-bearing walls and three-layer brick barrel vaults. The partitions and floors are made of terracotta, and the rest of the elements are made of dry-laid wood and steel. The green roof also provides the building with thermal inertia. In the words of the architects, the project and its construction aim to make the building itself “the first educational material of the school,” revealing itself for what it is (Gradolí and Sanz 2021, p. 139). The result has been published in national and international journals, and has been monitored for the achievement of BREEAM and GREEN seals, demonstrating that a design based on local mechanisms and materials can be efficiently combined with contemporary energy requirements.

3.3. IBAVI , Social Housing, Palma de Mallorca, 2021

The Balearic Islands Institute of Housing (IBAVI) is a government office whose architects are developing a consistent social housing program aimed at achieving local-based sustainability. These dwellings are intended for social rental for families who only pay 30% of their income and have basic services financed. The objective is to achieve the highest possible thermal inertia through the strategy of space distribution and materiality. Thus, the building has a linear shape and cross ventilation to take advantage of the sea breeze.

The apartment block reuses construction strategies of traditional architecture (Figure 8). In fact, it uses *marès* sandstone, the island's local building material –extracted from a quarry 18 km away– but which, in recent years, had been replaced by more contemporary-looking materials in keeping with social preferences. The recovery of the material, promoted by recent directives, is reactivating the quarries and also generating an economy of proximity. Thus, the structure is built with *marès* sandstone walls as a heavy envelope with a low carbon footprint, the floor slabs with barrel vaults supported on *marès* pilasters and the roofs with wooden trusses and boards, covered with ceramic tile. The 30 cm-thick cover roof insulation is made of sheets of dried *posidonia oceanica*, a seaweed available 11 km (7 miles) from the site. According to the architects, "using sun-dried *posidonia* as a building material associates habitation with the balanced use of the resources of the surrounding ecosystems" (Reina et al., 2022, p. 175).

The layout of the apartments is remarkably contemporary and reminiscent of the more flexible typologies experimented by the masters of modernity. Based on an absolutely modulated compositional pattern, they have a thick envelope, which incorporates niches for storage, and a central section where the bathroom is located. Everything else is a versatile space, designed to be freely compartmentalized using easily removable materials such as wood (Figure 9). The added value of this project lies in the combination of local expertise and knowledge gained from the development of the architectural profession.

For all these reasons, the project has been recognized in different architectural awards, which endorse its architectural quality and provide concrete data. Qualitatively, the building has obtained an energy class A –the highest energy efficiency rating according to European Union Energy performance certificates– with a maximum air-conditioning demand of 7.49kWh/m^2. Quantitatively, the housing development has been built with only four contractors and a budget of 1,200 €/m2, financed with the Sustainable Tourism Tax of the Balearic Islands (Reina et al., 2022, p. 177).

4. Discussion

The three cases analyzed show similarities and differences in certain parameters that can be categorized according to three types of strategies. Here we will distinguish between spatial, constructive and management strategies. The first relate to the form and definition of the space, how the building is opened or closed, how it is protected from light or how its functionality is conceived. The second refer to the technical knowledge that is applied in the design, while the third concerns the understanding of the building as a device that can adapt to environmental conditions and resources.

The comparative table (Figure 10) includes the parameters observed, distinguishing, according to the intensity of the colour, the relevance of this in the overall conception of the building. More intense colours are related to more effective solutions in the achievement of the analysed parameter. In addition, small descriptive notes are added that allude to the measure adopted. For example, courtyards - private outdoor spaces - are present in all three buildings, but in the case of the social housing in Palma de Mallorca, being unique and uncovered, this element is more important for the functioning of the building as a whole. Similarly, the ways of filtering light and providing shade vary in the three cases, from protection by means of double façades in the case of the Barcelona civic centre to the design of deep porches with plant filters in the school in Valencia. In other cases, the solutions are very similar: the three cases analysed use very thick façade walls or include user-operated devices for opening and closing spaces.

However, the parameters included in the table cannot be considered as stand-alone categories. In fact, a design decision may have consequences on one or several sets of parameters. The modular conception of spaces is generally used to provide flexibility to the design, and is closely related to the functional management that the user will make throughout the useful life of the building (changing some rooms for others, extending or dividing spaces, etc.). In addition, cross-ventilation strategies are used to make the building an active device, which can be modified by the user.

The chart on the right-hand side of the table (Figure 10) shows the most common relationships observed between categories. It can be seen that some parameters share some common features, and that there is a certain relational density around the parameters of "tradition knowledge", "user management" or "active house".

5. Conclusions

5.1. Circularity as Degrowth

Seen from the perspective of the analysis of the "Life Cycle Energy Consumption of Buildings" –a concept already related to the Mosque of Cordoba– Km0 architectures are a shining example of sustainability. Embodied Energy, or the energy required for the construction of the building, is reduced to a minimum when local material resources are used and buildings are repurposed. Operational Energy, or the energy required for building operation, is optimized with passive design strategies. If, in addition, and as in the case studies analyzed, these buildings are designed to last over time –consistent envelopes– and their useful life exceeds the standards in other conditions, then the impact of Embodied Energy, in the whole of its cycle, is even lower. In this way, the time factor seems to be decisive in the way these architectures are conceived.

The design is not considering a specific life cycle and, therefore, in the recovery of materials for the day after, but it is taken for granted that the lifespan of the building will generously exceed the possibility of reuse of its components. This way of creating architecture does not constantly feed the construction industry and, consequently, challenges the system of continuous economic growth.

Circularity thus reaches its shortest loop, where the least energy is needed to maintain the value of an asset. Consequently, and to a certain extent, the idea of growth is put at risk. The vision of the Ellen McArthur Foundation has always been Restorative and Regenerative, and some authors have already underlined that this institution, a leader in the development of the EC, is an "alternative growth discourse" and not an "alternative to growth discourse" (Charonis 2012, p. 80). The fact is that the most efficient circularity is akin to the concept of Degrowth, that which Latouche defined as that whose "goal is to build a society in which we can live better lives whilst working less and consuming less" (Latouche 2009, p. 9). Nowadays, the voices calling for degrowth as the only possible path to sustainability are becoming louder and louder, an idea that has been transferred to the field of professional practice and teaching of architecture.

5.2. Practical Implications and Recommendations

The preceding discussion yields design strategies that could be considered as recommendations for efficient design or possible construction policies at the local level. Km0 architecture manifests a commitment to design with high thermal inertia, not only due to the materiality, but also to the spatial definition rooted in a given context. These are low-consumption, low-emission and low-energy architectures. Nevertheless, they are the drivers of a cultural identity that takes up traditional construction systems and adapts them to the present times. These are architectures that also contribute to a social economy that utilizes local trades and methods. These are probably not the paradigm of dismountable, flexible or prefabricated buildings, but they are prepared to be adaptable and to accommodate other functions throughout their useful life. The key seems to lie in a consistent and well-assembled envelope that works efficiently from exposed, light, and changeable interior finishes (wiring and plumbing systems, and dry partition walls). Ultimately, these are architectures that combine tradition and modernity, and that go beyond the maximum ratings of the green ranking systems; because what really matters is that they contribute to environmental, economic and social sustainability.

These findings suggest potential indicators that could analyze the impact of sustainability based on the Km0 concept in architecture. Architectural practice is understood as professional know-how that is rarely the subject of scientific impact. However, the methods and results of the design strategies studied here could lead to a global reflection –a comparative analysis of cases in other geographical areas can be carried out– and to a local adaptation, highlighting the values of one's culture. These indicators would assess existing works and commission awarding processes in architectural competitions.

Figures

Figure 1. HArquitectes, Cristalería Planells Civic Centre in Barcelona, 2017. Outside view. (Credit: Adrià Goula)

Figure 2. Gradolí & Sanz arquitectes, Imagine Montessori School in Valencia, 2019. Outside view. (Credit: Mariela Apolonio)

Figure 3. IBAVI, Social Housing in Palma de Mallorca, 2021. Outside view. (Credit: José Hevia)

Figure 4. HArquitectes, Cristalería Planells Civic Centre in Barcelona, 2017. Floor plans, cross-section and environmental performance diagrams of the complex. (Credit: HArquitectes)

Figure 5: HArquitectes, Cristalería Planells Civic Centre in Barcelona, 2017. Views of the interior of the complex. (Credit: Adrià Goula)

Figure 6: Gradolí & Sanz arquitectes, Imagine Montessori School in Valencia, 2019. Ground plan and cross section. (Credit: Gradolí & Sanz)

Figure 7: Gradolí & Sanz arquitectes, Imagine Montessori School in Valencia, 2019. Views of classrooms. (Credit: Mariela Apolonio)

Figure 8. IBAVI, Social Housing in Palma de Mallorca, 2021. Interior views of the apartments. (Credit: José Hevia)

Figure 9. IBAVI, Social Housing in Palma de Mallorca, 2021. Floor plans and cross section. (Credit: Carles Oliver, Antonio Martín, Xim Moyá, Alfonso Reina)

Figure 10. Comparative table of the case studies analyzed. (Credit: the authors)

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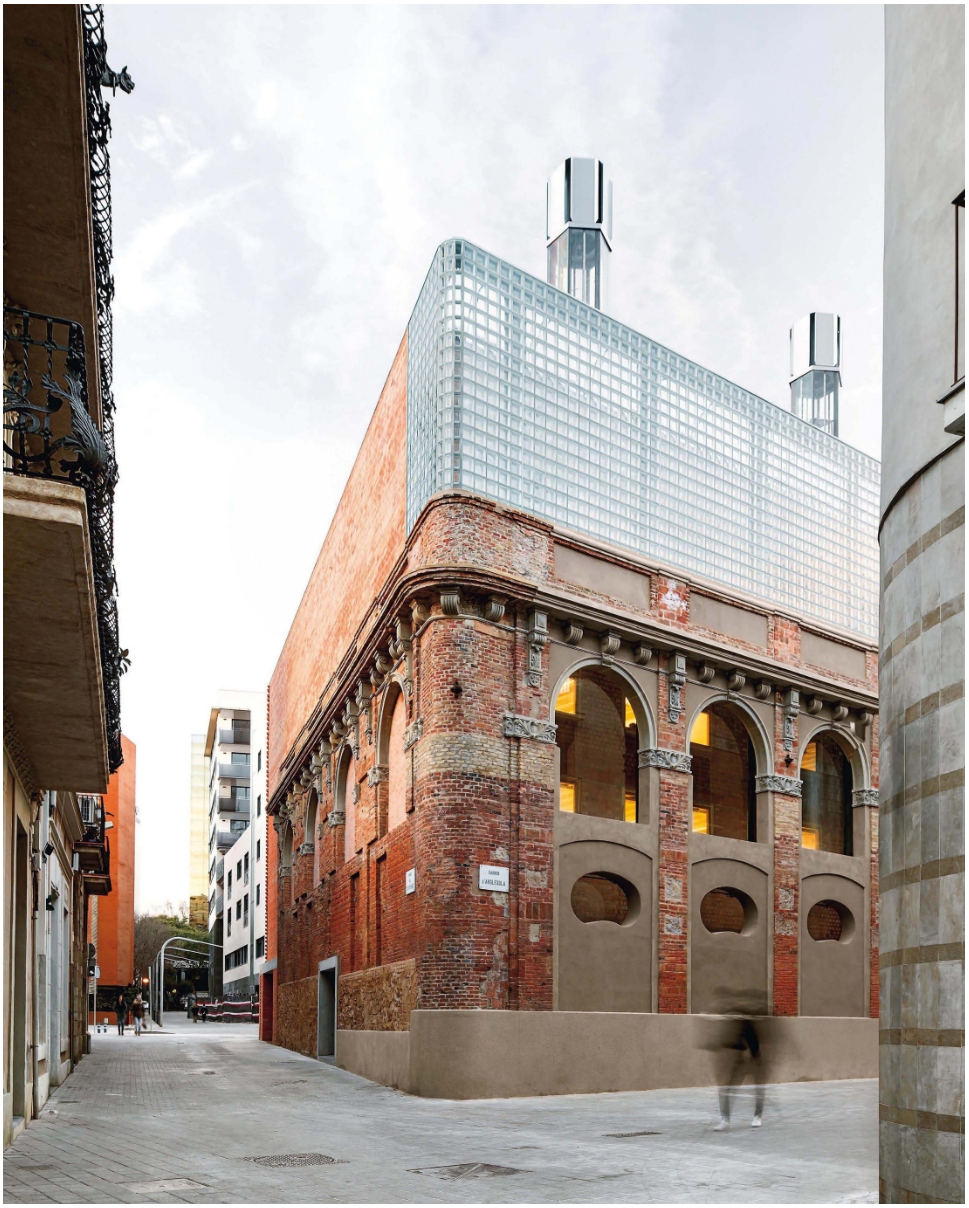


Figure 1. HArquitectes, Cristalería Planells Civic Centre in Barcelona, 2017. Outside view. (Credit: Adrià Goula)

224x279mm (300 x 300 DPI)

Figure 2. Gradolí & Sanz arquitectes, Imagine Montessori School in Valencia, 2019. Outside view. (Credit: Mariela Apolonio)

279x157mm (300 x 300 DPI)

Figure 3. IBAVI, Social Housing in Palma de Mallorca, 2021. Outside view. (Credit: José Hevia)

279x225mm (300 x 300 DPI)

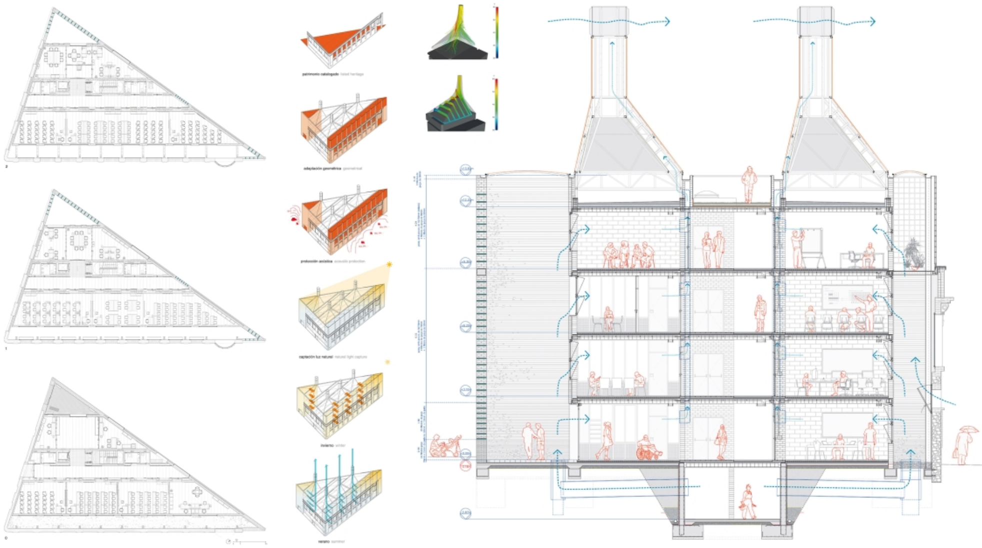


Figure 4. HArquitectes, Cristalería Planells Civic Centre in Barcelona, 2017. Floor plans, cross-section and environmental performance diagrams of the complex. (Credit: HArquitectes)

279x152mm (300 x 300 DPI)

Figure 5: HArquitectes, Cristalería Planells Civic Centre in Barcelona, 2017. Views of the interior of the complex. (Credit: Adrià Goula)

257x279mm (300 x 300 DPI)

Figure 6: Gradolí & Sanz arquitectes, Imagine Montessori School in Valencia, 2019. Ground plan and cross section. (Credit: Gradolí & Sanz)

42x59mm (762 x 762 DPI)

Figure 7: Gradolí & Sanz arquitectes, Imagine Montessori School in Valencia, 2019. Views of classrooms. (Credit: Mariela Apolonio)

84x48mm (300 x 300 DPI)

Figure 8. IBAVI, Social Housing in Palma de Mallorca, 2021. Interior views of the apartments. (Credit: José Hevia)

279x187mm (300 x 300 DPI)

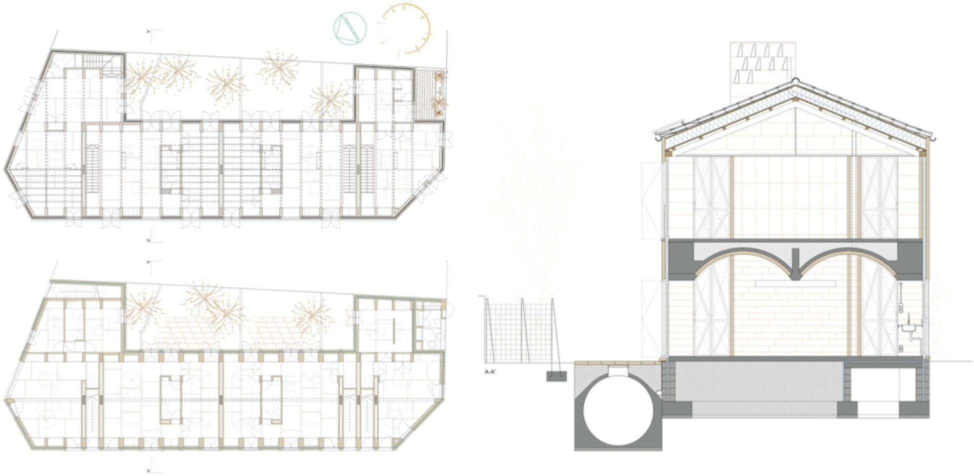
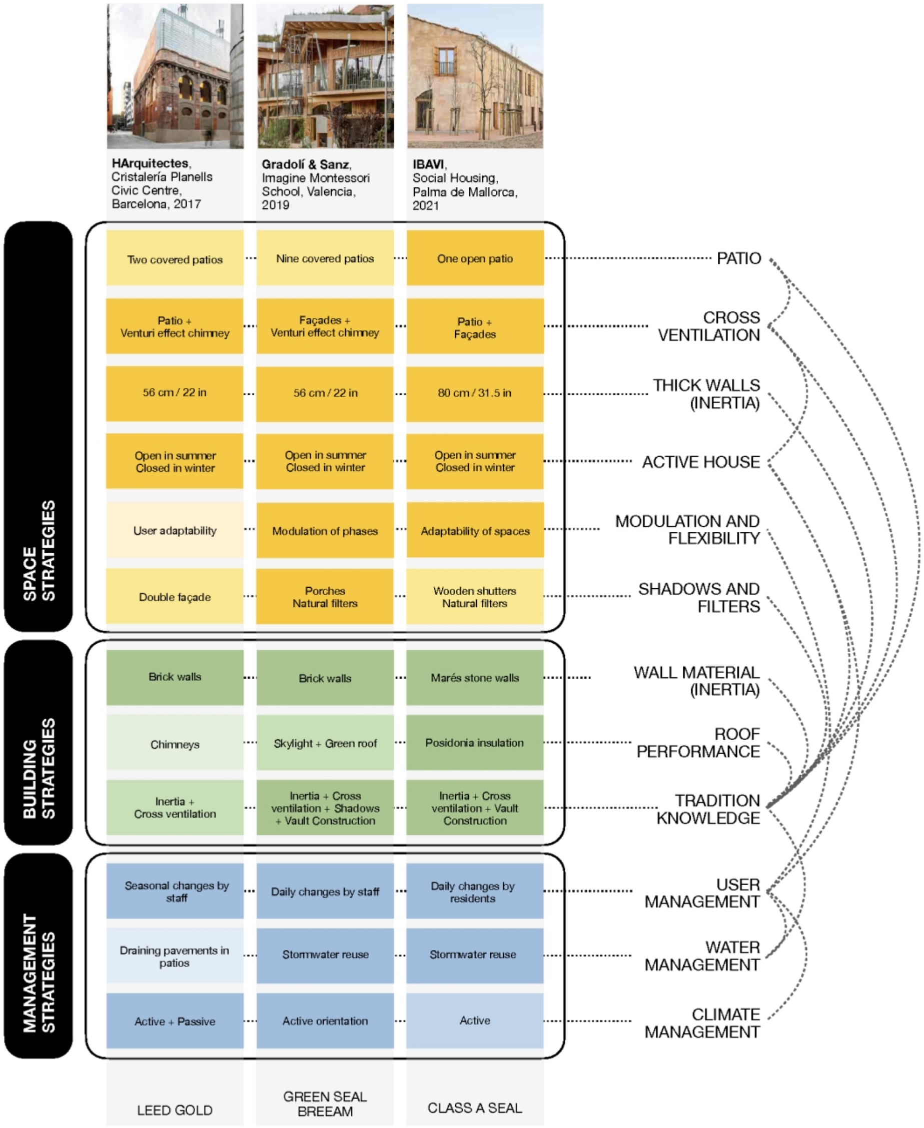


Figure 9. IBAVI, Social Housing in Palma de Mallorca, 2021. Floor plans and cross section. (Credit: IBAVI)

150x74mm (300 x 300 DPI)



		HArquitectes, Cristalería Planells Civic Centre, Barcelona, 2017	**Gradolí & Sanz**, Imagine Montessori School, Valencia, 2019	**IBAVI**, Social Housing, Palma de Mallorca, 2021
SPACE STRATEGIES	PATIO	Two covered patios	Nine covered patios	One open patio
	CROSS VENTILATION	Patio + Venturi effect chimney	Façades + Venturi effect chimney	Patio + Façades
	THICK WALLS (INERTIA)	56 cm / 22 in	56 cm / 22 in	80 cm / 31.5 in
	ACTIVE HOUSE	Open in summer Closed in winter	Open in summer Closed in winter	Open in summer Closed in winter
	MODULATION AND FLEXIBILITY	User adaptability	Modulation of phases	Adaptability of spaces
	SHADOWS AND FILTERS	Double façade	Porches Natural filters	Wooden shutters Natural filters
BUILDING STRATEGIES	WALL MATERIAL (INERTIA)	Brick walls	Brick walls	Marés stone walls
	ROOF PERFORMANCE	Chimneys	Skylight + Green roof	Posidonia insulation
	TRADITION KNOWLEDGE	Inertia + Cross ventilation	Inertia + Cross ventilation + Shadows + Vault Construction	Inertia + Cross ventilation + Vault Construction
MANAGEMENT STRATEGIES	USER MANAGEMENT	Seasonal changes by staff	Daily changes by staff	Daily changes by residents
	WATER MANAGEMENT	Draining pavements in patios	Stormwater reuse	Stormwater reuse
	CLIMATE MANAGEMENT	Active + Passive	Active orientation	Active
		LEED GOLD	GREEN SEAL BREEAM	CLASS A SEAL

Figure 10. Comparative table of the case studies analyzed. (Credit: the authors)

150x174mm (300 x 300 DPI)