Gomos modular system, Vale de Cambra, Portugal, photo by Building Pictures.

Design for disassembly and cultural sites. The use of modular architecture and prefabrication in exhibition venues

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Abstract: The article discusses the use of modular architecture and prefabrication in exhibition venues, looking at the possibility of designing installations with multiple temporalities. Through four concrete experimentations, we discuss ways of repurposing precast modules in new layouts with different functional programs in line with the "design for disassembly" concept. The article also emphasises the relevance of the massive residential construction programme based on modular and prefabricated systems launched by the German Democratic Republic in the mid-1970s, and the importance of reducing the environmental impact of concrete production today. Moreover, aiming at the need to devise new strategies, it presents a research agenda towards the adoption of prefabricated modules for the cultural sector. The four cases presented here are derived from the experimental use of modular solutions by the Porto-based practice SUMMARY: the GOMOS system indicates that prefabricated modules may have a longer lifespan than traditional building layouts, as they can be repurposed, making their reuse economically viable and environmentally friendly; the "Infrastructure-Structure-Architecture" installation at La Biennale 2016 reflects on possible adjustments in the construction industry; the project for the 2018 YAP MAXXI showcases the design process of a temporary installation that becomes a permanent building; and the VR exhibition "The Reasons Offsite" addresses prefabrication as a portable dissemination project.

Keywords: Modular architecture; Prefabrication; Portugal; Exhibition design; Design for disassembly; Concrete.

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1. Introduction

The worldwide adoption of industrialised building techniques in the second post-war period offered faster, cheaper, and safer methods of construction. Prefabrication in concrete has a long history that is inextricably intertwined with how factories have improved manufacturing processes (Fernández-Ordóñez Hernández, 2019). And it has taken on new importance in recent years, as cities struggle to accommodate a rapidly growing population and construction costs continue to rise.

In this article, we discuss experimentations with modular architectures for exhibition installations realised by the Porto-based practice SUMMARY. The projects trace a coherent trajectory based on the experimental use of modular solutions, demonstrating the viability of prefabrication as a means of meeting the challenges of the 21st century. Each project poses cultural, political, economic, and technical issues that show how multifaceted the prism of prefabrication is.

In this issue of Vitruvio dedicated to innovative design for sustainable cultural places, we present the evolution of a prefabricated module. We track its development from conception to its various applications. The module can be used for temporary exhibitions and later reassembled into a small-scale building. This perspective discusses how individual architectural elements can have a longer life cycle through various configurations, making travelling exhibitions and temporary pavilions the first stage of an adaptive reuse strategy.

Recent estimations place concrete in second place as the most consumed material by mass, with its manufacturing process responsible for 9% of the global anthropogenic CO_2 emissions and 3% of energy use (Monteiro et al., 2017). For this reason, it is crucial to devise new strategies to reduce the environmental impact of concrete production. In this text, we will focus on experimentations to make the life cycle of concrete structures more resilient through modular systems that are diachronically reusable, especially in the cultural sector. Küpfer et al. (2023) portrayed the landscape of reuse practices by reviewing 77 case studies of Piecewise Reuse of Existing Concrete in new Structural assemblies (PRECS). They underline the importance of studying the existing built stock and building techniques of the past to develop appropriate know-how, in a contemporary context where equivalent or upcycling reuse of concrete elements is relatively scarce.

In Europe, Germany has developed several initiatives at the institutional level on the reuse of concrete architectural elements as a viable strategy given the widespread *Plattenbau* housing (Mettke et al., 2008, Asam, 2007). Other experimentations involved Switzerland and France (Küpfer et al., 2023).

The “designing for disassembly - DfD” concept addressed in this article is thoroughly examined in a study by Wasim Salama (2017) in which it is suggested that theories and practices are to be brought together to increase the disassembly potential concrete buildings retain. This is the perspective we aim to adopt in the following examples. Design for disassembly was introduced in the 1990s in relation to a wide range of consumer products (Knight, 1996).

In architecture, the Arch of Constantine in Rome is one of those historical landmarks that symbolise a late-roman attitude towards construction and representation by repurposed elements, the so-called *spolia*. Existing materials from the past were being reused as ready-made pieces to be composed in a fresh layout. In Constantine’s case, the arch aimed to assert fictive continuities with previous great emperors by recycling sculptural elements that belonged to other monuments (Brilliant and Kinney, 2016). In the recent past, the reuse of building materials has met concerns about landfill saturation and environmental damages. In the United States alone, every year one billion square feet of existing buildings are demolished and replaced with new ones, while in 2030 half of the built landscape will have been built after 2000 (Merlino, 2018). Design for disassembly and reassembly is one way to face building obsolescence, emphasising the importance of assessing and designing the overall life cycle of the built environment. Modular prefabrication makes salvaged material easier to dismantle and more valuable for future use. In this scenario, systems and materials with no layers in the building are better separated, having “circumstances that require that either the design be rethought or a higher tolerance for deterioration be accepted” (Knecht, 2004: 186).

DfD also requires a proper regulatory framework, in which today the Netherlands and Denmark are considered the benchmark for other countries that still lag behind (Brewer and Mooney, 2008).

Hence, we aim to contribute to this debate, in which Portuguese applications are scarce, by presenting first a historical precedent from East Berlin that inspired our research; secondly, the introduction of the GOMOS system designed by SUMMARY (Figure 1); then we discuss three examples of modular architecture for exhibition venues; and finally we draw a research agenda towards the adoption of prefabricated modules for the cultural sector.

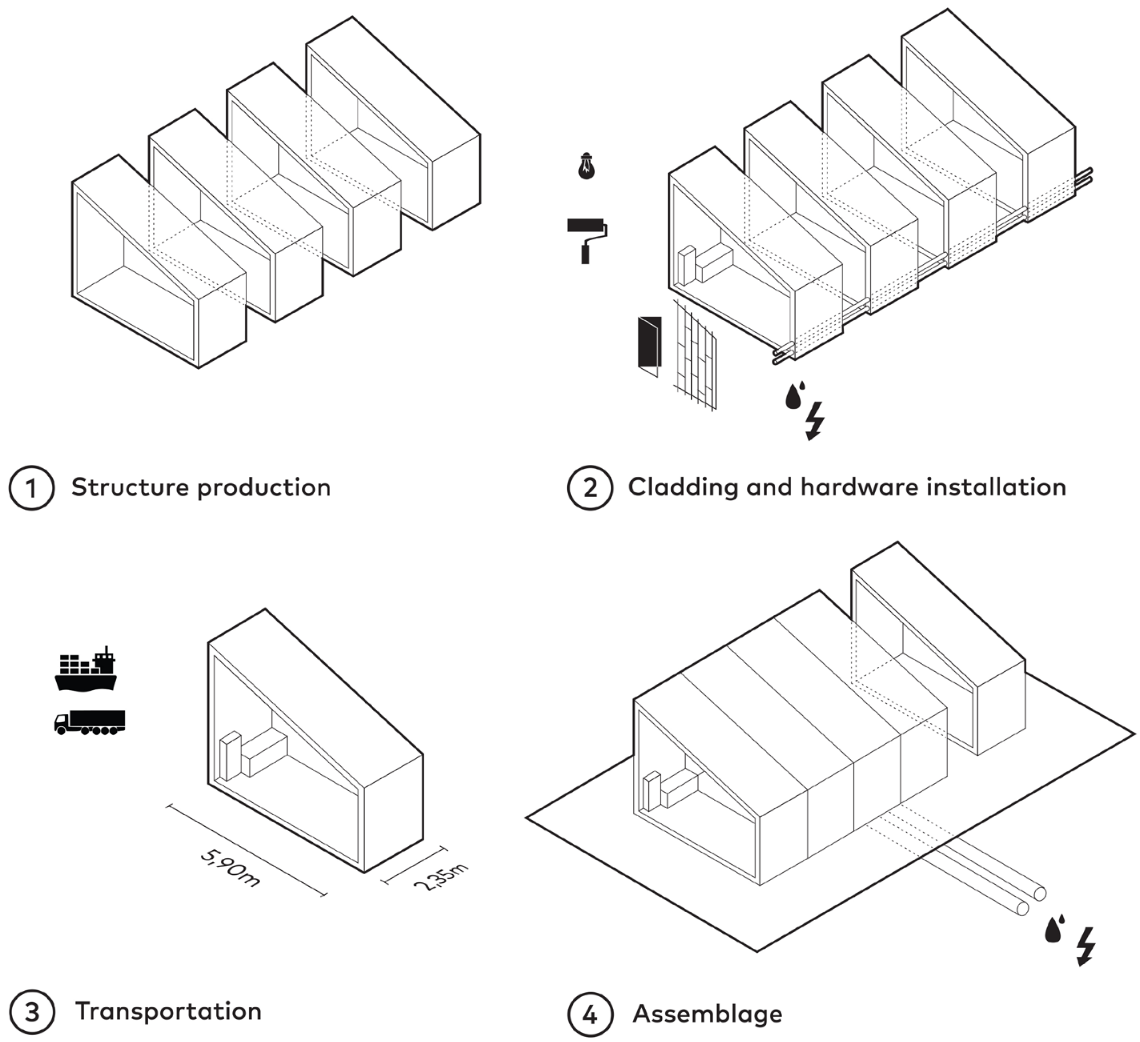


Figure 1 | GOMOS building process, credits: SUMMARY.

2. Disassembling and reassembling concrete panels in the DDR

Applications of prefabricated elements in the construction industries manifested as early as the first part of the 18th century. Between 1945 and 1970, the use of closed systems with large panels consolidated and reached its period of maturity (Fernández-Ordóñez Hernández, 2018). In a defining point of modernity, in the mid-1970s, the German Democratic Republic (*Deutsche Demokratische Republik*) launched a massive residential construction programme based on modular and prefabricated systems, with the aim of eradicating its housing deficit by 1990. Marzahn (East Berlin) was the epicentre of this programme, becoming the largest collective housing project in European history (de Graaf, 2017). The target was met, but the programme reached its goal when it was no longer needed. After the fall of the Berlin Wall, the DDR suffered massive emigration (Glorius, 2010), and where there had been a housing shortage, there was now a surplus. In fact, in the 1990s, a process of partial demolition – or rather dismantling – of buildings began, with two objectives: on the one hand, to eliminate the surplus housing supply; on the other, to transform those neighbourhoods into urban areas with Western standards. Reiner De Graaf (2017: 47) observes that in this process of normalisation (*Normalisierung*), the number of floors was reduced and the façades were insulated with polystyrene, hiding the joints that delimited the prefabricated panels. The inherent modularity allowed the buildings to be quickly dismantled, panel by panel, and reassembled in a new configuration in line with the renewed socio-political climate. Some were shipped abroad for new uses.

Similar programmes of modernisation of the built stock in East Germany consisting of disassembled and reassembled concrete components, based on the systems WBS 70, P2, PN 36-NO, were implemented in Dresden-Gorbitz, Eggesin, and Templin (Mettke et al., 2008). Since 2000, the state started to support such projects of recycled prefabricated units, also showing some limitations: the use of fixed patterns leads to limitations on the design of the foundations; the reuse of connecting space (corridors, staircases) is disproportioned against usable surfaces in low-rise buildings; if the structure requires adjustments/ extensions with masonry element, the construction is delayed. Overall, the amount of good, recyclable material in DDR-type buildings is calculated as 38% (Asam, 2007).

Utilising building parts that require extensive production procedures can increase profitability in recycling efforts. This encompasses parts that involve a significant amount of craftsmanship, have high wage costs, and require a great deal of work. Building parts that are particularly energy-intensive, such as concrete prefabricated parts, can be economically viable for reuse.

Concrete's energy-intensiveness is largely due to its high cement content, which binds aggregates together. However, reusing concrete prefabricated parts is 50% cheaper than producing comparable new concrete parts (Asam, 2007). Furthermore, this advantage will only improve with the ongoing escalation of energy prices (Monteiro et al., 2017).

These cases show one fundamental paradigm that guided the GOMOS research: that the lifespan of prefabricated modules exceeds that of the whole building per se, which is a paradoxical condition compared to what usually happens in architecture.

3. Pilot projects: on-field experimentations of precast modular systems

3.1 The GOMOS modular system

GOMOS is a building system prototype developed by a multidisciplinary team to address the need for simplified and faster construction processes (Figure 1). This system comprises modular, prefabricated, and evolutionary modules that can be completely finished, insulated, and equipped with water and electricity installations, window frames, and fixed furniture pieces at the factory (Figure 2). The modules are then transported to the construction site and assembled within a few days by joining them. The idea behind this system is inspired by the construction systems of sewer pipes. The team redesigned this system to make it habitable while maintaining the stability and rapidity of canalisation shells (Video 1).

The GOMOS, as well as other modular systems, poses three main research questions: what aspects are taken into account that are not considered in a bespoke project? What influence does the architect have on the production line of a prefabricated module? How is transportation a relevant aspect in the conception of a modular unit?

Kolbeck et al. (2023) show that modularisation strategies for precast constructions require a strict harmonisation of architectural design with structural engineering and building site management. Structural requirements are generally similar to non-modular projects, but each design decision should take standardisation and scalability into consideration. They found out that "an evolution is observed from the inflexibility of closed systems to open and individualised systems. This transition illustrates a significant industry shift, moving from uniform mass production towards the potential of mass customisation to allow architectural diversity while ensuring scale effects" (Kolbeck et al., 2023: 16). Building up in this direction, GOMOS is a versatile system that can be used for various programs, not just housing, and allows for further construction expansion with new modules.

This building was designed as a tubular geometry with larger openings at its ends, allowing for natural ventilation throughout the entire structure. The building's solar orientation and a fireplace for the coldest winter days work together to regulate the internal temperature and humidity. No mechanical installations, such as air conditioning, are needed to maintain a comfortable indoor environment. The module's dimensions allow simple transportation without any special requirements, according to applicable laws. Their design should favour efficient handling of the pieces, as shown in Figure 3, despite their substantial weight of 23 tons each.

Each module has 2.35 m x 5.9 m (width x length). The thickness of the reinforced concrete structure is the same in the four faces of the module (16 cm). The formwork of each module is made using a single mould, which means the four faces – the floor, the roof and the two walls – are cast together at the same time as a unique and volumetric piece. Modules can be produced in two different ways: as a single-layer, 16cm thick, reinforced concrete ring, which then will receive an additional insulation and cladding layer (Figure 4, left); or as a three-layer element, combining the same structural 15 to 18cm of reinforced concrete, plus 5 to 8 cm EPS or XPS insulation and an external cladding layer of concrete with 7 cm, completing a total thickness of 30 cm (Figure 4, right). In this case,

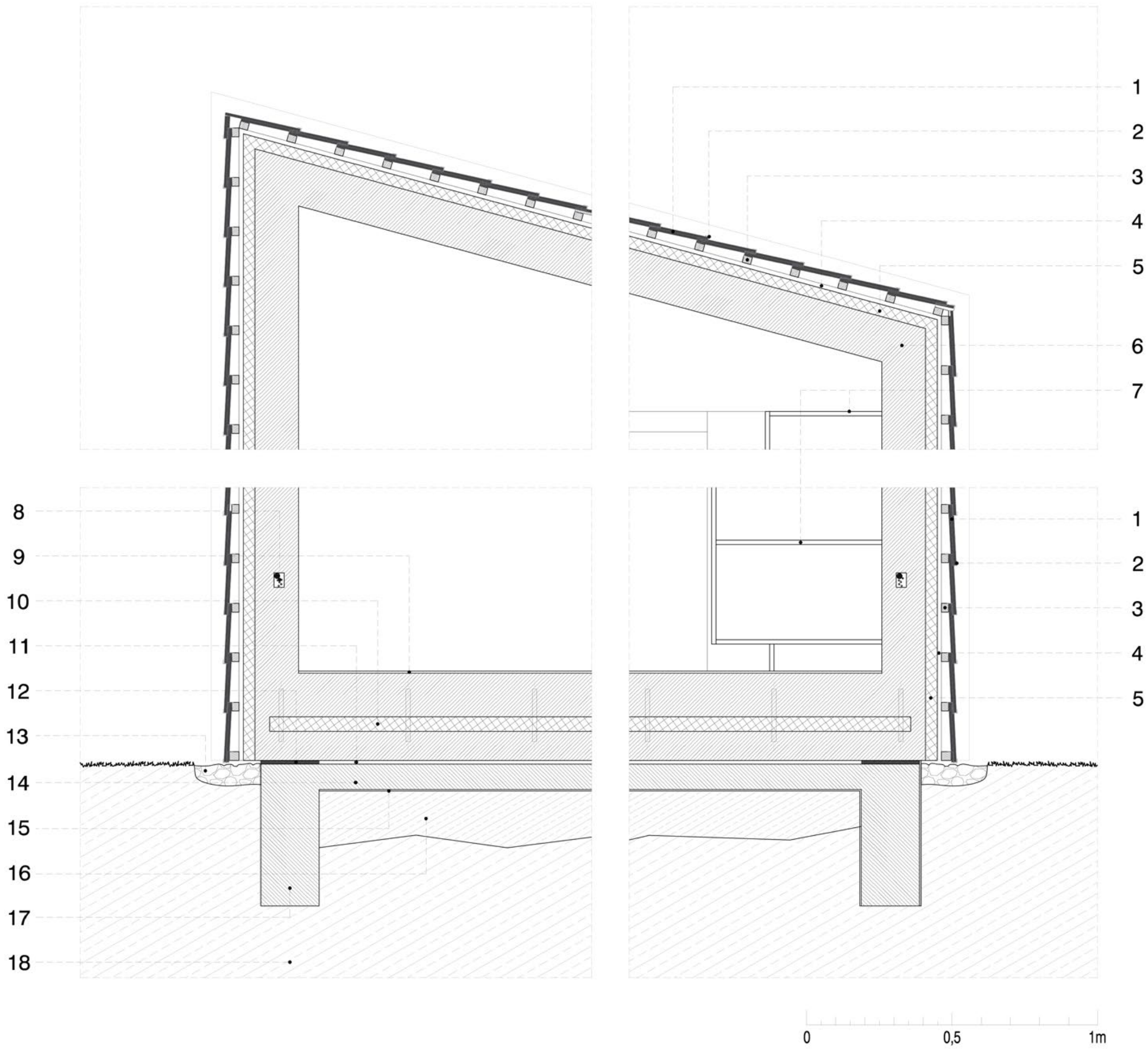
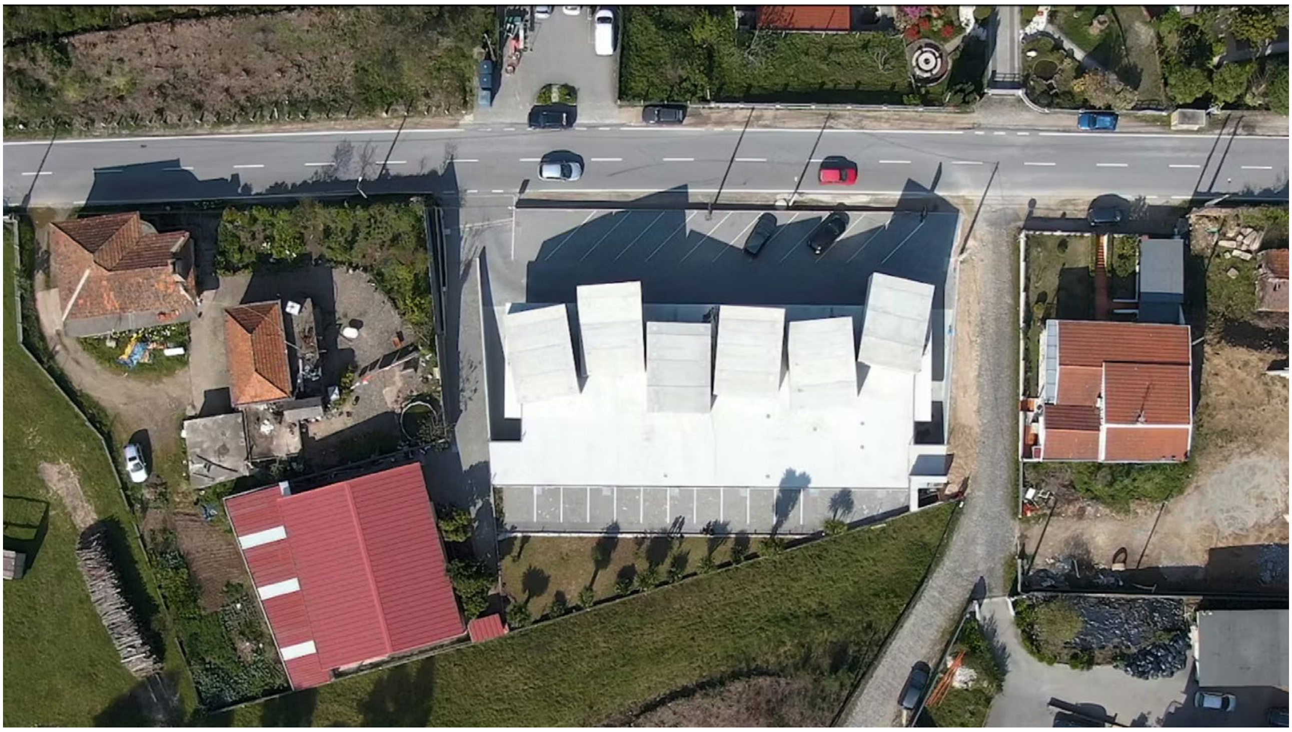


Figure 2 | Detail of the GOMOS module, credits: SUMMARY. 1 slate tiles; 2 steel hooks; 3 wooden slats; 4 wooden counter-slats; 5 thermal insulation (XPS); 6 precast concrete module; 7 MDF / kitchen cabinets; 8 built-in electric gutter; 9 epoxy resin coating; 10 thermal insulation (XPS); 11 20 mm air box; 12 20 mm plastic shims; 13 white pebble stone; 14 foundation slab; 15 waterproofing screen; 16 150 mm compacted gravel; 17 foundation beam; 18 natural ground.

the internal structural concrete and the external cladding concrete are linked through some punctual connectors, and the whole piece, including the insulation layer, is cast together at once. Either way, for both situations (the single-layer or the three-layer element), the modules' production time is similar, normally corresponding to 3 to 4 days, depending on external factors, such as temperature and humidity, that influence the drying process. This period can increase up to 6 days when the modules require some additional technical work, such as the inclusion of exceptionally complex plumbing or wiring systems.

An important part of the technical performance of the system lays on the joints in between the different modules, and the way they are connected. Each one of these joints are complemented with 6 connectors (2 in each wall, and 2 in the roof) which comprise the modules and make them work together in structural terms. Plus, its tongue and groove configuration not only enhances structural integrity but also contributes to waterproofing of the joint when no additional external cladding is present. Inside each joint, there's an asphalt-based sealant that is compressed once the connectors are tightened, ensuring no water or air can pass through this gap (Figure 5).



Video 1 | GOMOS System _ PREFABRICATION credits: Building Pictures. https://youtu.be/pViNpqekfqk

Figure 3 | On-site handling of the module, video still, credits: Building Pictures.

Figure 4 | Concrete sample cylinders of the GOMOS module. Single-layer 16cm thick on the left; triple-layer 30 cm think on the right, credits: SUMMARY.

Figure 5 | Connector between modules, credits: SUMMARY.

3.2 Infrastructure - Structure – Architecture installation at La Biennale 2016 in Venice

The first public presentation of SUMMARY's research on modularity took place in Venice at the Biennale Architettura 2016, curated by Chilean architect Alejandro Aravena and titled "Reporting from the Front". The team proposed a set of prefabricated elements for the main outdoor exhibition piece at the Arsenale venue (Figure 6).

The installation titled "Infrastructure - Structure – Architecture" elaborates on the adaptation of specific industrial processes to architectural needs, presenting three pieces, placed in a seemingly evolutionary order, that leads from a piece of infrastructure to a domestic space. Indeed, the study of the cross section is a point of departure in the scalability of a production process to be introduced in a precasting plant (Steinle et al., 2019). The installation proposes adapting the production line of concrete sewer pipes, which is available globally, to create accessible industrial solutions for modular architecture (Figure 7). The final step is a larger shed-roof module that functions as a structure that frames future transformation with manifold possibilities of composition (Figure 8).

Additionally, the last module features a table with two screens that simultaneously display videos for a comparison between the construction process of the GOMOS system and that of the pieces for infrastructures.

3.3 2018 YAP MAXXI competition: a modular exhibition transformed into a medical centre

The third step of the experimentation reflects on the flexibility of precast concrete modules, looking at how they can be repurposed for different functions and layouts in a way that makes a closed-loop material process possible. Namely, the story of a temporary installation becoming a permanent building. The context of this project is the YAP MAXXI 2018, the Young Architects Program organised by the National Museum of 21st Century Arts (MAXXI) in Rome, in collaboration with MoMA New York as a counterpart of the PS1 program. Emerging architects are given the possibility to design a temporary installation that occupies Piazza Alighiero Boetti, in front of Zaha Hadid's building, for the duration of the summer season (MAXXI, 2020). The core requirement is that of offering shelter from the heat while reconfiguring a public space that connects two main streets of the Flaminio neighbourhood. SUMMARY's proposal, titled "What Happens Next (?)", was among the five shortlisted for the 2018 edition (Figura 9).

After the effort and energy put into the construction of the Biennale installation, previously presented, the exhibited pieces just crashed, transformed into garbage.

In this new proposal, as the title suggests, the studio interrogates on what happens after temporary installations realised for cultural sites are no longer needed. Is it possible to avoid, at least partially, producing additional debris? Is there a way to act on the lifecycle of temporary design?

Figure 6 | Installation of Infrastructure - Structure - Architecture, credits: Tiago Casanova.

This seems paradoxical as temporary constructions are meant to be disposable by definition. Hence, the challenge would be that of aligning the temporalities of two projects by using the same material, like a building blocks game. Because the project governs the four phases of production (exploitation of natural resources, transformation, transportation, installation), in the conception phase architecture offices can strategise how to disassemble and reassemble their work. In this way, they establish a specific form of material circularity that follows most of the guidelines suggested for circular economy in the building sector (Minunno et al., 2018).

In this case, it was proposed that the precast modules be reassembled in a first-aid medical centre to support displaced people (children and women of childbearing age) living in Rome who need social and health care. The operational side of the proposal was drafted in collaboration with an international association, *Diritti al Cuore*, which has operated as a recognised ONLUS in the region since 2010 (Diritti al Cuore, 2023). It was intended as a small contribution in scale, not a charitable gesture, but rather as a pragmatic optimisation of the investment and material allocated to the exhibition.

Hence, the design process has to start from the final step, the final configuration of the building according to the needs of the association, then proceed backwards to compose an installation with the disassembled elements, and finally, their production. The phases of the life cycle of the construction are represented in Figure 10.

At the MAXXI, the installation is designed as a “concrete pergola” that lacks visual unity. It is intended as a building site for something that is awaiting its completion (SUMMARY Architecture, 2018). The concrete modules support artworks and shelter the passers-by.

The horizontal beam is equipped with an integrated solar energy system that activates ventilation, water pulverisation, and illumination only when it senses

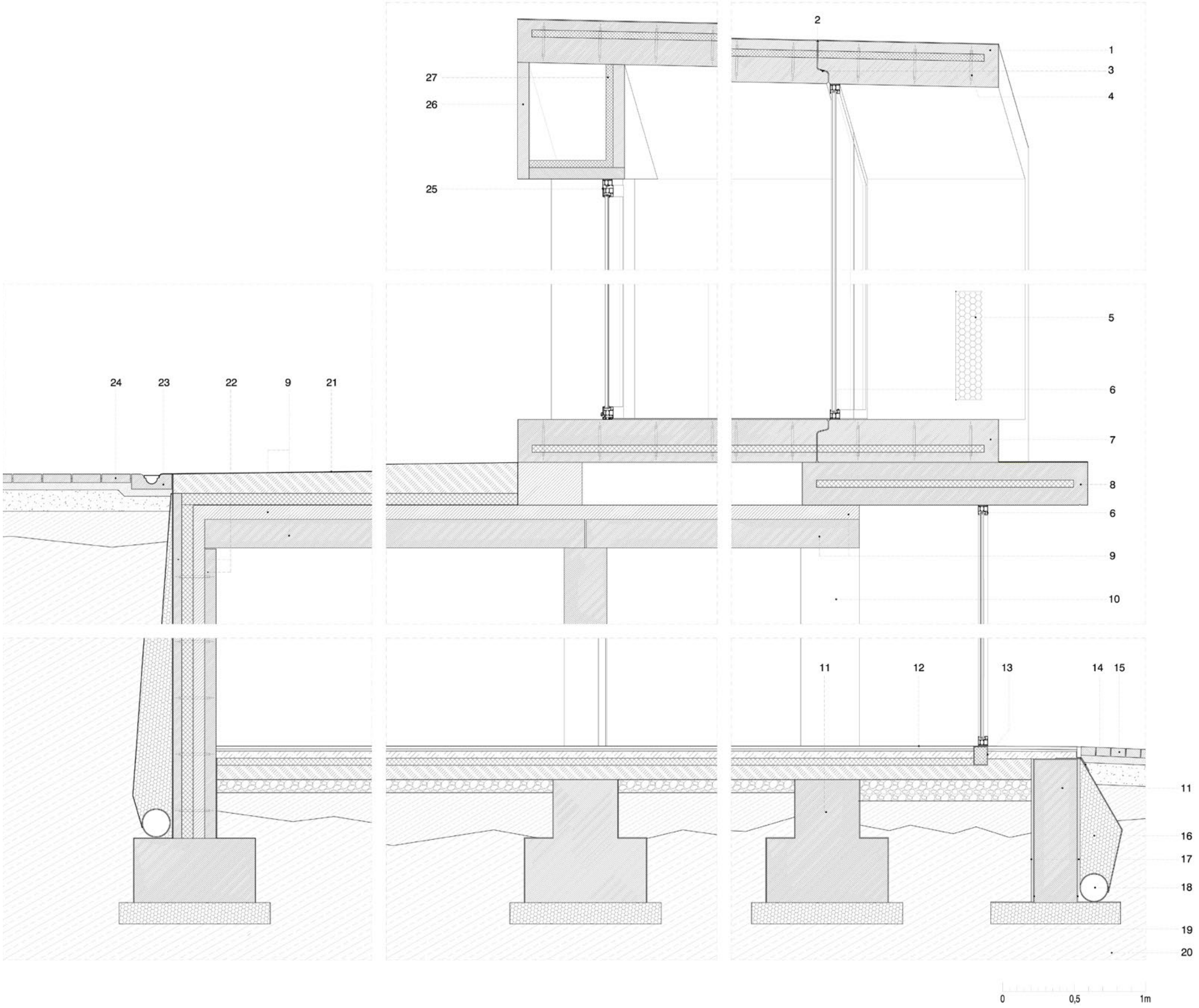


Figure 7 | Detail of an application of the GOMOS module for housing, credits: SUMMARY. 1 - ca. 1, 7 / 2.5mm flexible, elastic single component polyurethane waterproofing membrane over prefab concrete module: 70 mm cladding precast concrete; 50 mm thermal insulation XPS layer; 180 mm load-bearing precast concrete (all assembled in factory). 2 - mastic based joint sealant. 3 - asphalt based sealant. 4 - concrete modules' steel connector. 5 - stainless steel wire rope mesh "Jakob Rope Systems - Webnet", rope 0 1.5mm, mesh aperture 40 mm; tied to tensioned stainless steel cable 08.0 mm, anchored by screw terminal spiked in concrete walls. 6 - aluminum window frame with thermal cutting and double glazing. 7 - self-leveling epoxy resin interior floor coating, over prefabricated reinforced concrete module: 180 mm load-bearing precast concrete; 50 mm thermal insulation XPS layer; 70 mm precast concrete. 8 - liquid aliphatic polyurethane waterproofing membrane, over prefabricated concrete slab: 125mm precast reinforced concrete; 50 mm XPS insulation; 125mm precast reinforced concrete. 9 - 100 mm concrete poured "in situ", over 200 mm precast reinforced concrete "preslab". 10 - precast concrete pillar (in projection), 410 mm length, 80 mm-300 mm width. 11 - reinforced concrete "in situ" foundation; 150 mm compact gravel. 12 - transparent, two-pack epoxy resin-based varnish; 20 mm cast in-situ, polished concrete pavement; 15mm leveling cement layer; 50 mm mortar cement layer; 50 mm XPS insulation layer; 100-145mm lightweight concrete; 150 mm compacted gravel; ca. 250 compacted terrain. 13 - 100x135mm metallic frame, for window frame attachment, with insulation inside. 14 - 5mm asphalt membrane. 15 - 200x100x60 mm precast rectangular concrete paver; ca. 50 mm sand; ca. 150 mm "tout-venant" (sand, gravel and cement mixture); ca. 250 mm compacted terrain. 16 - 22-32 mm gravel for water drainage system. 17 - drainage PVC membrane. 18 - 200 mm PVC drainage pipe. 19 - waterproofing asphalt painting. 20 - natural soil. 21 - liquid aliphatic polyurethane waterproofing membrane, over 135mm (min.) lightweight concrete, ca. 1.3% slope; 80 mm XPS insulation layer; waterproofing asphalt painting. 22 - drainage PVC membrane; waterproofing asphalt painting; earth retaining prefab concrete wall: 60 mm precast reinforced concrete panel; 80 mm XPS insulation layer; 80 mm air gap to be filled with concrete in-situ; 80 mm precast concrete panel (all assembled in factory). 23 - prefab concrete trench drain/gutter, covered with stainless steel drainage grid. 24 - 400x200x60 mm precast rectangular concrete paver; ca. 50 mm sand; ca. 150 mm "tout-venant" (sand, gravel and cement mixture); ca. 250 mm compacted terrain. 25 - aluminum hinged door with thermal cutting and double glazing. 26 - aqueous acrylic varnish protection layer for concrete, over 80 mm prefab reinforced concrete panel. 27 - 50 mm XPS insulation layer; 80 mm prefab reinforced concrete panel.

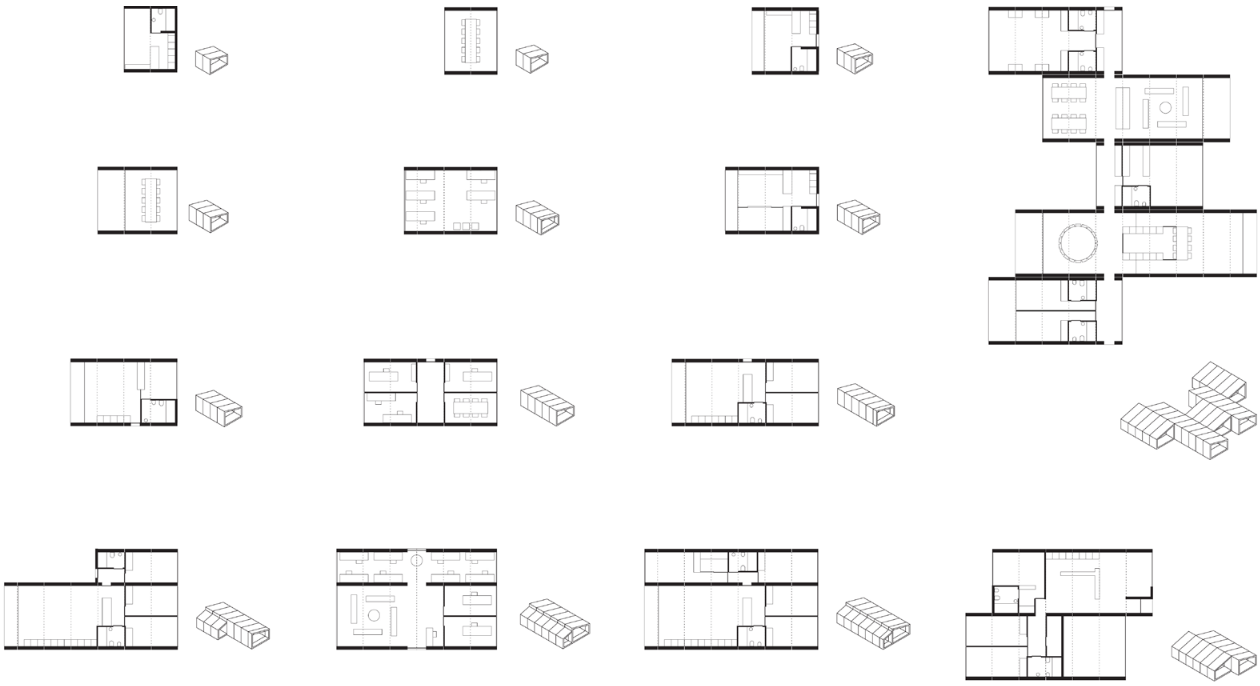


Figure 8 | Installation of Infrastructure - Structure - Architecture, assemblage of modules, credits: SUMMARY.

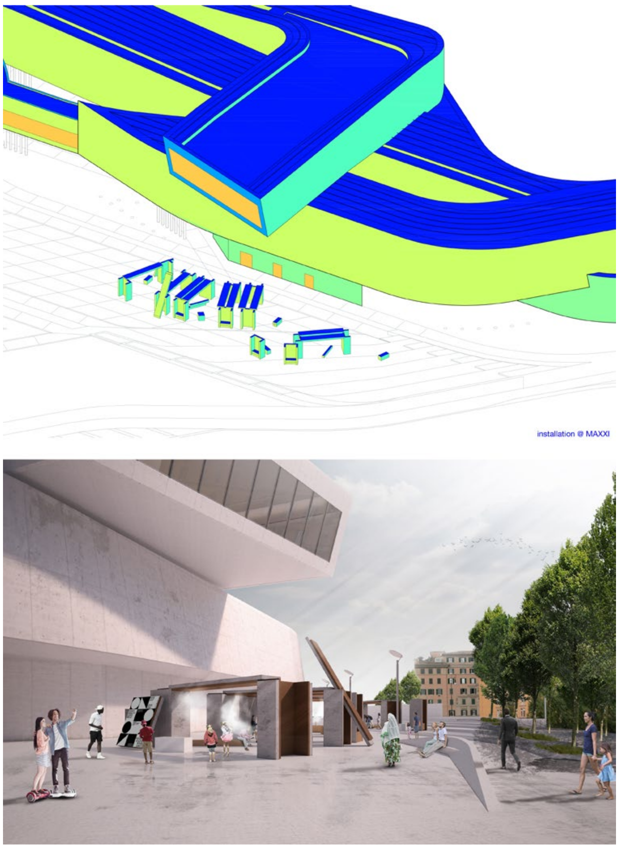


Figure 9 | Installation "What Happens Next (?)" shortlisted at the 2018 YAP MAXXI, credits: SUMMARY.

someone's presence nearby. The thermal comfort is improved with a biocooler smart system that operates within a radius of six metres (Figure 11).

Natural cork functions as a coating for concrete panels, working as a protection layer during transportation and as thermal insulation in the final building. As shown in Figure 12, the elements composing the overall installations are of four types: one C-shaped module, with two different heights, with a standard 2 m x 1 m footprint, for vertical structure; a series of elongated planar elements, 1m wide, for bridging the structure to form a regular rood; one or more rectangular panes to enclose the internal space.

The proposal wasn't implemented, yet it contributed to the acquisition of expertise for additional initiatives the team has been working on in Portugal. A key element refined for the reuse of precast modules involves the creation of lifting anchors and connectors for the modules.

The former requires a recessed space where a metal cover with a rubber neck is sealed with a waterproofing coating as shown in Figure 5.

The fact that all the concrete elements are prefabricated not only allows their replacement, as they can be easily detached from each other and from the floor, but also plays a central role in the embodied carbon reduction of the installation. This is confirmed by an estimation

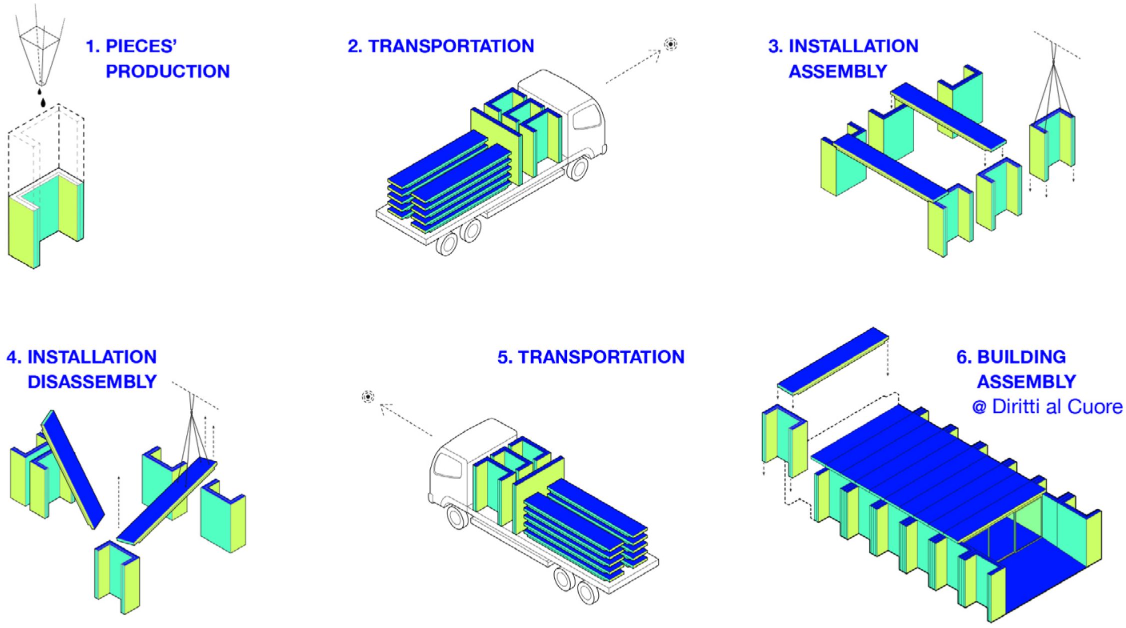


Figure 10 | Life cycle of the installation "What Happens Next (?)", credits: SUMMARY.

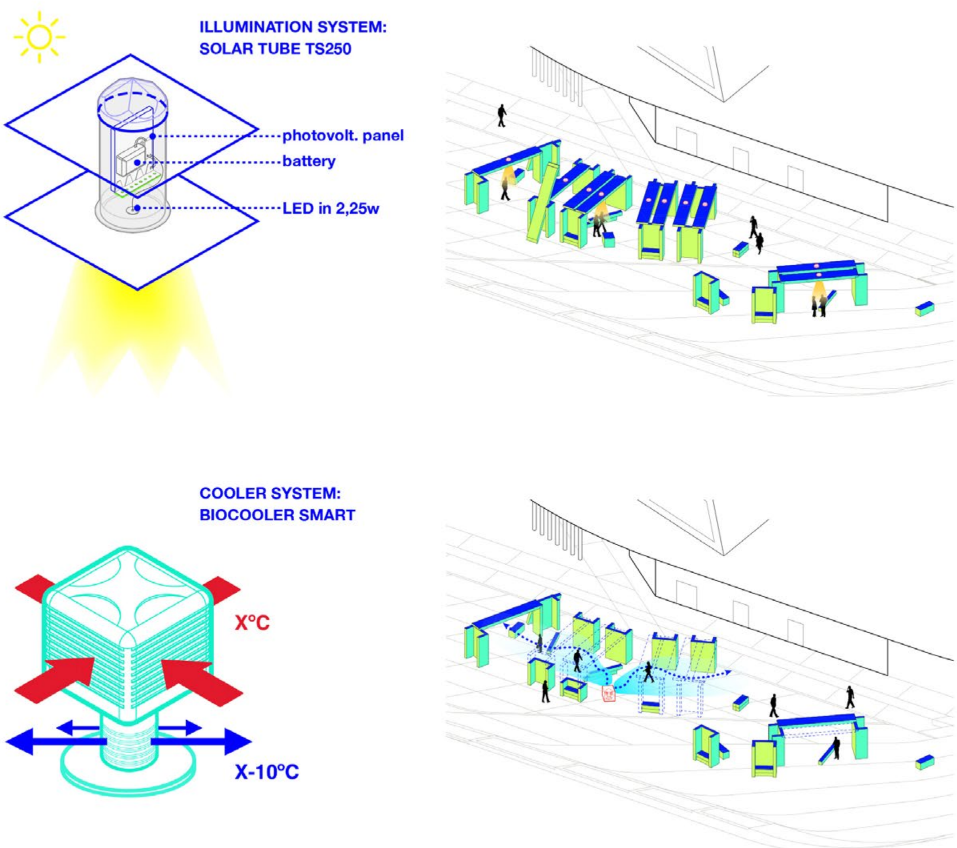


Figure 11 | Illumination and cooling system of "What Happens Next (?)", credits: SUMMARY.

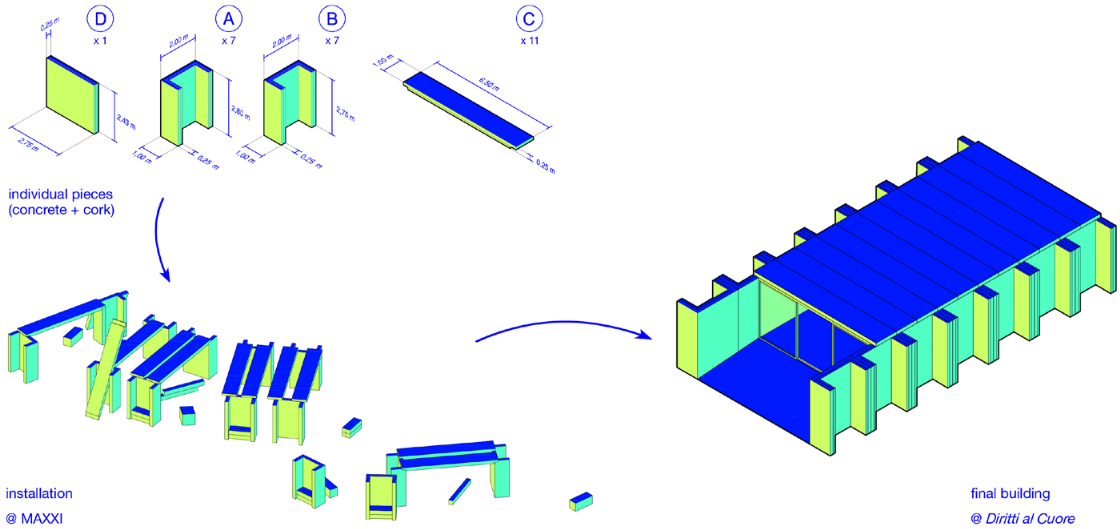


Figure 12 | Elements of “What Happens Next (?)”, credits: SUMMARY.

Table 1 | Carbon footprint comparison.

Type of construction	Total volume (m^3)	Installation embodied carbon (tCO_2)		“new building” embodied carbon (tCO_2)	Total (tCO_2)
PREFABRICATED SYSTEM	44.4	24.25*	Disassembly + Transport + Assembly	5.33**	29.58
CAST-IN-PLACE CONCRETE	44.4	28.81***	Demolition + New Construction	26.80****	55.61

* This calculation includes: Production [A1-A3] 19.16 tCO_2, Transport [A4] 3.44 tCO_2, Construction [A5] 0.25 tCO_2 (material) + 1.4 tCO_2 (global).
** This calculation includes: Transport [A4] 3.44 tCO_2, Construction [A5] 0.49 tCO_2 (material - considering disassembly and assembly) + 1.4 tCO_2 (global).
*** This calculation includes: Production [A1-A3] 23.50 tCO_2, Transport [A4] 0.56 tCO_2, Construction [A5] 1.34 tCO_2 (material) + 1.4 tCO_2 (global), End of Life [C1-C4] (demolition) 2.01 tCO_2.
**** This calculation includes: Production [A1-A3] 23.50 tCO_2, Transport [A4] 0.56 tCO_2, Construction [A5] 1.34 tCO_2 (material) + 1.4 tCO_2 (global).

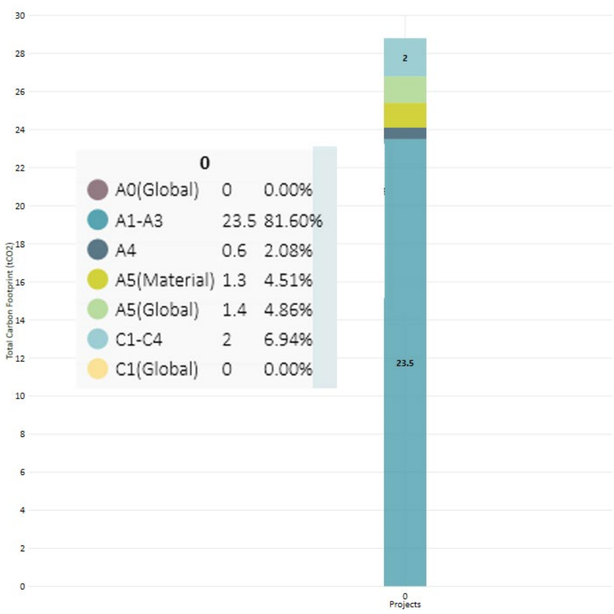


Figure 13 | Distribution of carbon footprint, credits: Carbo Life Calculator.

calculated through the *Carbo Life Calculator*, a plugin integrated with *Autodesk Revit*, and the ECI (embodied carbon intensity) of specific materials associated with this plugin database. The same volume of concrete used in this project would be higher if it was produced in a “traditional” manner instead of prefabricated. This conclusion has been verified in practical terms in other projects completed by SUMMARY, such as the mixed-use building in Vale de Cambra that is presented in Figure 7. In that case, there is a 18cm layer of load-bearing precast concrete; then a 5cm gap with XPS thermal insulation; and finally a 7cm layer of precast concrete.

The Table 1 presents a comparison study between the prefabricated system we proposed for the MAXXI installation and its subsequent reassembly as a “new building” versus the same constructions (installation + new building) using a cast-in-place concrete structure. Both

Video 2 | The Reasons Offsite credits: Casa da Arquitectura. (https://youtu.be/7cxWUfW-gdY)

cases consider the same volume of material (44.3 m^3), focusing exclusively on the concrete structural elements. Notes:

- Each transport is calculated considering a 50km distance.
- For the "New Building" the calculations do not include the "end of life" of the constructions.
- For the "Prefabricated System" we considered "Concrete UK C40/50 – Precast".
- For the "Cast in Place Concrete" we considered "Concrete C32/40 Upper Bound".
- The calculation process is available at this link.

As an example, a graphic analysis of the cast-in-place situation is presented below, where the embodied carbon for each phase of the installation construction, life, and destruction is discriminated (Figure 13).

3.4 VR exhibition: The Reasons Offsite

The final step of the research on precast modules for cultural sites is a virtual exhibition, "The Reasons Offsite", which is in itself the design of a portable equipment kit that fits regular aeroplane luggage dimensions. It is based on Oculus Rift System VR technology and comprises a package containing four projectors, two PCs, and one Oculus Rift setup. As such, it has travelled to the Boston Society of Architects in March 2019; to the BAUHAUS Centenary, at Neufert Box Weimar, in September 2019; to the KEK – Contemporary Architecture Centre Budapest in October 2019; and lately to Casa da Arquitectura – Portuguese Centre for Architecture in June-October 2022.

It is now established that VR applications are part of museum strategies to reach a more diverse audience and disseminate complex topics to a vast audience (Resta and Dicuonzo, 2024).

The offsite approach is considered the appropriate architectural solution for the challenges mentioned above. However, history shows that it hasn't been successful in most cases due to factors like conflicts and competing forces at play. In "The Reasons Offsite" exhibition, various conflicts are analysed from the different perspectives of participants, including Yona Friedman, Pablo Jimenez-Moreno, Pedro Alonso & Hugo Palmarola, and Jorge Christie & Martín Alvarez. The conflicts discussed include standardisation vs. customisation, machination vs. humanisation, science vs. art, and more.

The exhibition is divided into two parts. The first part of the project aims to showcase a collection of significant buildings and building systems that have played a crucial

Figure 14 | VR Environment of "The Reasons Offsite", credits: Casa da Arquitectura / Ivo Tavares.

role in the historical evolution of offsite architecture. The goal is to provide a comprehensive overview of the various stages of this evolution. The content is designed to answer four essential questions: when, where, how, and why. This information is presented in a virtual reality environment, where each case is represented by a corresponding 3D model, text, and picture material. The medium choice offers visitors an immersive experience, where they can explore 25 different buildings from around the world, all collected in a 20 mX20 m virtual space (Figures 14-15).

The second part of the exhibition consists of invited participants who share their thoughts and ideas on the subject. They do so through a display of projected texts and images. The participants discuss the previously mentioned conflicts and attempt to forecast future prospects for offsite architecture as well as its potential to address contemporary urban challenges.

The project composition offers a complex experience for the audience, beginning with the exploration of research material on offsite architecture in virtual reality, and followed by a critical reflection on its content.

The examples were selected without any preference for aesthetics or economic success. Instead, only the features that made them pioneers in the field of offsite construction were taken into account. The models are categorised into groups based on the main reason they were built for. These reasons include "exploration" (e.g. Manning Colonial Cottage in 1830s), "emergency situations" (e.g. Airoh House starting in 1944), "cost-optimization" (e.g. Sears Catalogue Homes starting in 1908), "technological advancement" (e.g. Crystal Palace in 1852), and "lifestyle paradigm" (e.g. Nakagin Tower in 1972).

The exhibition features an array of models set in an abstract space. Despite the presence of a reference system, visitors are free to chart their own course through the exhibition, making choices based on their personal preferences. The interactive exhibits also provide visitors with the ability to focus on specific themes, helping them to comprehend and decipher the intricate subject matter. For instance, visitors can opt to explore only the examples attributed to the cost-optimization group, disregarding all other categories.

4. Concluding notes for a design with multiple temporalities

We have seen that the main architectural challenges in designing precast concrete structures are tolerances and calculations for fit, production, transport, handling on site, and sustainability/life cycle (Steinle et al., 2019). In the sphere of the architectural project, “along-side the logistics, back-building and remounting plans must be combined with each other; legal construction regulations and financial aspects must be improved” (Asam, 2007: 1005).

Through the four experimentations presented above, we have addressed some of these challenges.

The growing need for speed and cost restraints enhanced by a globally accelerated society; the increasing housing demand in urban areas; the shortage of specialised labour in building sites are the main systemic conditions we have faced in these eight years. Prefabrication, in some cases, is one venue capitalist society uses to acquire portions of distant markets, with repercussions that are not only technical but also cultural, political, and economic (Shaw et al., 2022, Linder, 1994). At the same time, the GOMOS system and the YAP MAXXI project demonstrate that modularity is also adaptable to multiple scenarios, allowing the architect to design an entire production process and repurpose the precast elements. Those experimentation contribute to the advancement of strategies for the circular economy in the building sector, and especially what Minunno et al. (2018) call “Design toward disassembly of goods into components to be reused”, with the variation that such reuse is already embedded in a two-phase design process.

By designing these structures with modularity and flexibility in mind, architects can ensure that components are not just used for a single event but can be reassembled and repurposed for multiple applications over time. This not only extends the lifespan of the materials used but also promotes a sustainable approach to architectural design.

For instance, a pavilion constructed for an international expo can later be disassembled, and its parts used to create smaller, community-based structures such as public libraries, pop-up shops, or even temporary housing solutions. This method not only reduces waste and the demand for new materials but also allows for the cultural and artistic value of the original structure to permeate through various communities, enhancing public spaces with elements of high-quality design.

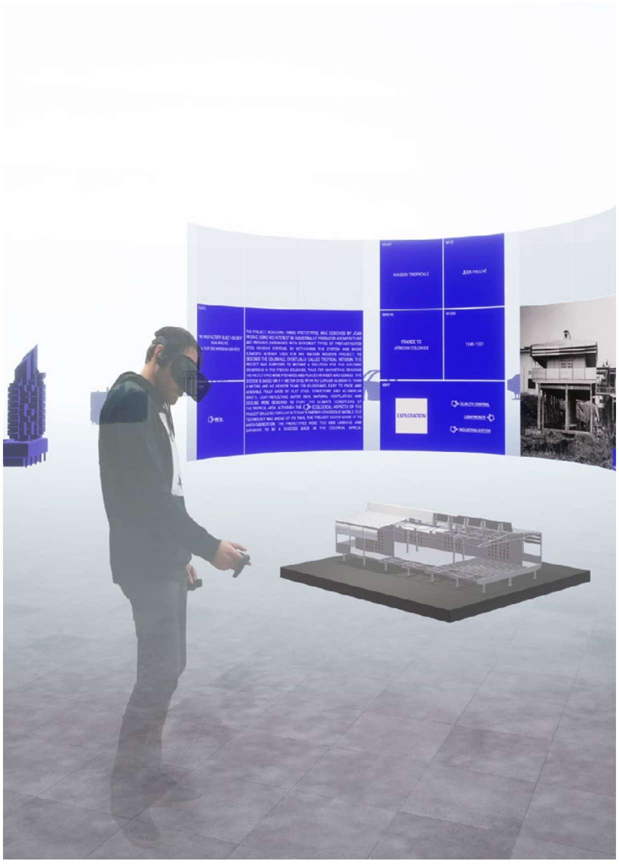


Figure 15 | VR Environment of “The Reasons Offsite”, credits: SUMMARY.

Moreover, this approach encourages architects and designers to think creatively about the lifecycle of materials from the outset, demanding innovative solutions in the use of sustainable and recyclable materials. It also challenges the industry to consider the environmental impact of construction projects, pushing for practices that minimise carbon footprints and promote ecological balance.

In the future, this research-by-design path portrayed in the text expects to develop in the following directions to contribute to the “design for disassembly” concept as a viable architectural strategy:

- The production of modules based on concrete and rice-husk-concrete to replace plastic insulations and avoid additional claddings and greatly reduce the carbon footprint of the building material. At this moment, SUMMARY Architecture is finishing the project of a house with such modules.

- Expand on three-dimensional systems such as Prefabricated Prefinished Volumetric Construction (PPVC), which allow the use of steel. SUMMARY is employing PPVC in three ongoing projects in Portugal.

- Popularise the use of installations with prefabricated modules to be employed after they are dismantled.

- Elaborate on the stigma of modular construction, coming from the post-war housing boom and the establishment of a narrative on the inhabitants as alienated subjects.

- Elaborate on the feedback collected in "The Reasons Offsite" exhibition.

As it is suggested by Knecht (2004), moving towards zero-waste building construction requires the participation of the entire industry. It is possible that in the future, architects will be responsible for producing deconstruction drawings and deconstructability reviews. Building elements will be labelled or bar-coded with disassembly instructions and constituent materials, which will significantly decrease the costs of demolition and deconstruction.

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References

Asam, C. (2007). Recycling prefabricated concrete components – a contribution to sustainable construction. *In:* Bragança, L., Pinheiro, M., Jalali, S., Mateus, R., Amoêda, R. & Correia Guedes, M. (eds.) *Portugal SB07: Sustainable Construction, Materials and Practices: Challenge of the Industry for the New Millenium.* IOS Press, Lisboa.

Brewer, G., & Mooney, J. (2008). A best practice policy for recycling and reuse in building. *Proceedings of the Institution of Civil Engineers: Engineering Sustainability,* 161, 173-180. 10.1680/ensu.2008.161.3.173.

Brilliant, R., & Kinney, D. (eds.) (2016). *Reuse Value: Spolia and Appropriation in Art and Architecture from Constantine to Sherrie Levine*. Routledge, London. https://doi.org/10.4324/9781315606187.

De Graaf, R. (2017). *Four walls and a roof: the complex nature of a simple profession*. Harvard University Press, Cambridge, MA.

Diritti Al Cuore. (2023). *La storia* [Online]. Available: https://www.dirittialcuore.it/en/chi-siamo/storia (Accessed 24 March 2024).

Fernández-Ordóñez Hernández, D. (2018) Published. Early Developments of Concrete Prefabrication. *In: Hordijk, D. A. & Luković, M., eds. High Tech Concrete: Where Technology and Engineering Meet*, 2018// 2018 Cham. Springer International Publishing, Cham, 2795-2801. https://doi.org/10.1007/978-3-319-59471-2_317

Fernández-Ordóñez Hernández, D. (2019). Concrete prefabrication. Lessons from the past and advances for the future. *Cement-Wapno-Beton = Cement Lime Concrete,* 24, 351-360. https://doi.org/10.32047/CWB.2019.24.5.2.

Glorius, B. (2010). Go west: internal migration in Germany after reunification. *Belgeo*. https://doi.org/10.4000/belgeo.6470.

Knecht, B. (2004). Designing for disassembly and deconstruction. *Architectural Record,* 192**,** 181-188.

Knight, W.A. (1996). Software tools to evaluate cost benefits and environmental impact of designing for disassembly, recycling and the environment. *Technical Papers, Regional Technical Conference - Society of Plastics Engineers.* Society of Plastic Engineers, Brookfield, CT.

Kolbeck, L., Kovaleva, D., Manny, A., Stieler, D., Rettinger, M., Renz, R., Tošić, Z., Teschemacher, T., Stindt, J., Forman, P., Borrmann, A., Blandini, L., Stempniewski, L., Stark, A., Menges, A., Schlaich, M., Albers, A., Lordick, D., Bletzinger, K.-U., & Mark, P. (2023). Modularisation Strategies for Individualised Precast Construction—Conceptual Fundamentals and Research Directions. *Designs* [Online], 7. 10.3390/designs7060143. https://doi.org/10.3390/designs7060143

Küpfer, C., Bastien-Masse, M., & Fivet, C. (2023). Reuse of concrete components in new construction projects: Critical review of 77 circular precedents. *Journal of Cleaner Production,* 383**,** 135235. https://doi.org/10.1016/j.jclepro.2022.135235.

Linder, M. (1994). *Projecting capitalism: a history of the internationalization of the construction industry*. Greenwood Press, Westport, CT.

Maxxi (2020). *YAP Rome at MAXXI*. MAXXI, Roma.

Merlino, K.R. (2018). *Building Reuse. Sustainability, Preservation, and the Value of Design*. University of Washington Press, Seattle, WA.

Mettke, A., Heyn, S., & Mettke, A. (2008) Rückbau industrieller Bausubstanz – Großformatige Betonelemente im ökologischen Kreislauf. BTU Cottbus. Fakultät für Umweltwissenschaften, Cottbus.

Minunno, R., O'grady, T., Morrison, G.M., Gruner, R L. & Colling, M. (2018). Strategies for Applying the Circular Economy to Prefabricated Buildings. *Buildings* [Online], 8. https://doi.org/10.3390/buildings8090125

Monteiro, P. J. M., Miller, S. A., & Horvath, A. (2017). Towards sustainable concrete. *Nature Materials,* 16, 698-699. https://doi.org/10.1038/nmat4930

Resta, G., & Dicuonzo, F. (2024). Towards a Digital Shift in Museum Visiting Experience. Drafting the Research Agenda Between Academic Research and Practice of Museum Management. *In:* Barberio, M., Colella, M., Figliola, A. & Battisti, A. (eds.) *Architecture and Design for Industry 4.0: Theory and Practice.* Springer, Cham. https://doi.org/10.1007/978-3-031-36922-3_3

Salama, W. (2017). Design of concrete buildings for disassembly: An explorative review. *International Journal of Sustainable Built Environment,* 6, 617-635. https://doi.org/10.1016/j.ijsbe.2017.03.005

Shaw, I., Jones, M.J., Flexner, J.L. & Bedford, S. (2022). Prefabrication, Patrilineality, and Intergenerational Reuse: The Ruined Third Church of Aniwa, Southern Vanuatu, and its Integration into Domestic Architecture. *International Journal of Historical Archaeology,* 26, 573-598. https://doi.org /10.1007/s10761-021-00615-6

Steinle, A., Bachmann, H., & Tillmann, M. (2019). *Precast Concrete Structures*. Ernst & Sohn, Berlin.

Summary Architecture. (2018). What Happens Next (?) Yap Maxxi 2018 Pavilion [Online]. Available: https://summary.pt/works/yap-maxxi/ (Accessed 18 March 2024)