ARCHITECTURE

Essays & Viewpoint

AGATHÓN – International Journal of Architecture, Art and Design | n. 14 | 2023 | pp. 152-163
ISSN print: 2464-9309 – ISSN online: 2532-683X | doi.org/10.19229/2464-9309/14122023

Article Info

Received	15 September 2023
Revised	08 October 2023
Accepted	20 October 2023
Published	31 December 2023

SISTEMI ABITATIVI MODULARI OFF-SITE
Soluzioni speditive per l'abitare da studenti

OFF-SITE MODULAR HOUSING SYSTEMS
Expeditious solutions for student residence

Oscar Eugenio Bellini, Marianna Arcieri, Maria Teresa Gullace

Abstract

In un sistema universitario competitivo, le residenze per studenti rappresentano un'ineludibile infrastruttura a supporto non solo delle esigenze di ospitalità ma anche delle attività didattico-formative, contribuendo a promuovere concetti di indipendenza e autonomia individuale e ad attivare scambi e supporti relazionali reciproci. Per dare risposte speditive all'attuale carenza di posti alloggio è oggi possibile far ricorso a sistemi abitativi modulari prefabbricati. Avvalendosi della letteratura e di case studies, il contributo traccia l'evoluzione di questo sistema costruttivo, evidenzia limiti e potenzialità e restituisce un quadro che definisce ragioni e opportunità che potrebbero suggerirne un maggiore impiego nell'housing universitario, in un momento in cui rapidità esecutiva, qualità del prodotto e rispetto dei costi realizzativi sono sempre più fattori dirimenti.

In a competitive university system, student residences represent an essential infrastructure to support not only hospitality needs but also educational and training activities, promoting concepts of independence, and fostering reciprocal relational exchanges and supports. In order to respond immediately to the current shortage of accommodation places, it is possible to use prefabricated modular housing systems. Thanks to the study of literature and case studies, this paper describes the evolution of this construction system, highlighting limits and potentials. It also provides an overview that defines the reasons and opportunities that could suggest its greater use in the university housing sector, at a time when the speed of execution, product quality and respect for costs are increasingly important factors.

Keywords

residenze per studenti, prefabbricazione, innovazione di processo e di prodotto, moduli abitativi, edifici temporanei

student residences, prefabrication, process and product innovation, housing modules, temporary buildings

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Per un sistema universitario che mira a essere competitivo a scala internazionale le residenze per studenti rappresentano un'ineludibile infrastruttura sociale a supporto dei processi di mobilità. Oltre a favorire la riduzione dei costi della formazione, sui quali la voce 'alloggio' incide in misura determinante (Hauschildt et alii, 2021), queste infrastrutture appaiono, sul piano sociologico, come la soluzione più appropriata per promuovere l'indipendenza e l'autonomia individuale, sperimentare la dimensione comunitaria, incoraggiare il confronto con gruppi eterogenei di persone, spesso di origine e cultura differenti, e favorire rapporti relazionali reciproci. Nonostante ciò la carenza di alloggi per studenti permane un limite con il quale si stanno confrontando migliaia di universitari fuori sede; in Italia solo il 5% degli studenti ha la possibilità di essere ospitato in questa tipologia abitativa (Fig. 1; Hauschildt et alii, 2021).

Per rispondere a questa 'emergenza abitativa', è possibile ricorrere all'impiego di sistemi abitativi modulari off-site, una soluzione costruttiva efficiente e versatile, molto utilizzata nella emergency housing, e recentemente nello student housing. In questi casi il modulo progettuale si può trasformare in uno strumento di espressività creativa, capace di governare, attraverso i principi dell'industrializzazione e della prefabbricazione, molteplici aspetti di processo e di prodotto, tra i quali, per esempio, semplicità e velocità costruttiva, qualità dei livelli prestazionali, rispetto della normativa ambientale e antisismica, controllo rigoroso dei tempi di esecuzione, ecc. (Dörries and Zahradnik, 2019; Russo Ermolli and Galluccio, 2019; Scalisi and Sposito, 2021).

L'Off-Site Modular Construction permette la realizzazione di edifici a complessità variabile, dove la cellula tipo si configura come un «[…] three-dimensional or volumetric unit that is assembled in a factory and delivered to a construction site as the main structural element of a building» (Lawson, Ogden and Goodier, 2014, p. 1), una modalità costruttiva con radici relativamente lontane nel tempo, segnata da interessanti sperimentazioni con caratteri ricorsivi nei suoi principi fondativi.

Prodromi | Qualsiasi considerazione sul concetto di modulo presuppone, sul piano teoretico, il confronto con gli studi e le ricerche di Carlo Giulio Argan (1965) raccolte in Progetto e Destino, un testo che ha indagato, in ambito disciplinare, l'evoluzione e il modificarsi rispetto al costruire, l'essere sintesi ed espressione culturale del concetto di modulo. La natura connotativa di queste ricerche ha permesso di definire l'assunto di 'modulo oggetto', quale principio ideativo della costruzione, e di 'modulo-misura', entità dimensionale astratta che, in architettura, può stabilire relazioni qualitative o quantitative tra le parti.

In termini evolutivi il 'modulo-oggetto', compendio dei concetti di 'modulo-compositivo', 'modulo-costruttivo' e 'modulo-tipologico', si è manifestato in molteplici situazioni: nelle strutture reticolari di Fuller, nella modularità addizionale di Utzon, nelle applicazioni sperimentali di tipo industriale di Wachsmann, nel concetto di edificio aperto di Habraken, nelle prototipizzazioni di Kurokawa, nonché nel Sistema Abitativo di Pronto Impiego di Spadolini (Tab. 1). Questo quadro evolutivo comprende anche le sperimentazioni di W. Gropius e J. Prouvè che, oltre a esplorare le potenzialità del modulo nell'ambito delle emergenze sociali legate all'abitare, hanno saputo ampliare il dibattito scientifico attorno al paradigma di flessibilità funzionale, spaziale e tecnologica.

Secondo Argan, il modulo-oggetto si trasforma in 'principio ideativo', diventando 'il fatto-base della costruzione'; diversamente dal modulo-compositivo, entità dimensionale virtuale utile a stabilire relazioni metriche quantitative o qualitative tra le parti, il modulo-oggetto consente all'architettura di introdurre un cambio di paradigma, facendo coincidere un'entità non fisica con un prodotto industriale finito.

A partire dagli anni '60 questi assunti vengono applicati alla residenzialità universitaria, restituendo sperimentazioni innovative, 'archetipi' paradigmatici, involontari modelli anche per le soluzioni più recenti. Tale processo può essere compreso solamente riferendosi alle trasformazioni culturali e disciplinari introdotte dal razionalismo degli anni '30, durante il quale il tema dell'abitare viene ricondotto a una questione meramente funzionale. A ciò si deve aggiungere la riconsiderazione del ruolo dell'utente come parte attiva nel progetto, che maturerà negli anni a seguire, cambiando il rapporto tra chi progetta e chi produce, immaginando una produzione di massa aperta anche all'architettura. Il progetto non appartiene più a un'élite, ma alla capacità di chi lo usa che, sulla base della sua creatività personale, lo interpreta, modifica e rigenera per dare risposte adeguate ai bisogni dell'uomo contemporaneo.

Ricadute sul progetto dell'housing universitario si hanno anche grazie agli Archigram e al loro manifesto interesse nei confronti delle nuove tecnologie e dell'industrializzazione. Nel 1960 Peter Cook, figura apicale degli Archigram, progetta Car Body / Pressed Metal Cabin, una casa pop per studenti, piena di gadget e prodotta in serie con moduli abitativi in plastica e metallo (Fig. 2) che da corpo a una soluzione lontana dalla staticità spaziale e dalla rigidità costruttiva delle soluzioni per l'abitare da studenti, materializzando una visione inusuale con rimandi alla letteratura fantascientifica e alla cibernetica, una sorta di trascrizione letterale degli entusiasmi per il design del settore automobilistico.

Nello stesso periodo Herbert Ohl, docente all'Intistute of Industrialised Building of Ulm, progetta il sistema Raumzellenbauweise (Short, 2021), composto da unità abitative modulari tridimensionali (Fig. 3) in calcestruzzo armato estruso (6,00 x 2,69 x 2,74 m), assemblabili tramite bullonatura agli angoli, in molteplici configurazioni morfologiche e spaziali. Il sistema si basa su un approccio sistemico, con attenzione alla sostenibilità ambientale, all'ottimizzazione dei materiali, alla semplificazione e rapidità costruttiva, al rapporto basso costo / alta qualità, alla reversibilità delle componenti, al loro ciclo di vita, ecc., proponendo paradigmi anticipatori di quelli che, a distanza di alcuni decenni, si trasformeranno nei protocolli per la certificazione ambientale.

Nel 1964 il tecnocratico Cedric Price presenta Potteries Thinkbelt, un progetto dalla forte carica innovativa, che diventa insostituibile fonte d'ispirazione per molte delle più recenti soluzioni abitative modulari per studenti (Vráblová, Czafík and Puškár, 2022; Fig. 4). Il Thinkbelt propone un linguaggio che allude esplicitamente all'estetica del mondo industriale e della meccanica (Lobsinger, 2000), prefigurando un'Università su rotaie per 20.000 persone da ospitare in capsule aggregabili, flessibili, adattabili, ricollocabili denominate 'sprawl', 'capsule', 'crate' e 'battery housing'. Secondo Price «[…] while students are at present one of the most mobile social groups of technologically advanced societies the nature of their own particular production plants – schools, colleges and universities – is static, introspective, parochial, inflexible and not very useful» (Price, 1970, p. 13).

Nell'evoluzione delle sperimentazioni abitative destinate alla residenzialità universitaria, il modulo-oggetto trova applicazione, sotto forma di elementi tecnici (bagni e cucine), anche nell'ambito del recupero del costruito. Intorno agli anni Settanta, nell'International Students Club, lo Studio londinese Terry Farrell & Nicholas Grimshaw Partnership propone l'utilizzo di componenti modulari preprogettati, preingegnerizzati e prefabbricati nel recupero di una serie di Terrace Houses di epoca vittoriana (Fig. 5). Il progetto prevede di affiancare all'esistente una Server Tower con una rampa a spirale che disimpegna una serie di servizi igienici modulari composti da sei diversi quarti di moduli prefiniti in plastica rinforzata che esemplificano, in modo quasi didascalico, le potenzialità della progettazione modulare applicata all'esistente.

Da questo quadro, seppur sintetico, emerge come lo student housing sia stato storicamente e continui ad essere un campo di sperimentazione non solo tipologica ma anche tecnologica. Oggi, sul piano costruttivo le aggregazioni dei moduli abitativi possono essere molteplici: per affiancamento, sovrapposizione e giustapposizione, con soluzioni bifacciali, parzialmente bifacciali, di supporto angolare, non portanti, a componenti, ecc. (Subramanya, Kermanshachi and Rouhanizadeh, 2020; Fig. 6), con sistema strutturale puntiforme, lineare o scatolare, autoportante o no, realizzato in cemento armato, acciaio o legno (Tab. 2); ogni brevetto ha prestazioni specifiche non generalizzabili, seppure prevalga la struttura autoportante con finiture a secco.

La funzione degli interni dei moduli è solitamente definita dagli spazi destinati alla camera da letto e al bagno. Il bagno, se ventilato naturalmente, si trova in prossimità dell'ingresso e all'unità abitativa si accede solitamente tramite un connettivo lineare (ballatoio), con conseguente contrazione del livello di privacy. Oltre a camera e bagno si possono avere altri spazi come angolo cottura, micro-soggiorno, balcone, ecc.; in questo caso il modulo ha quasi sempre uno sviluppo longitudinale, poiché la posizione del bagno permette di scomporre il layout della pianta in due distinte zone funzionali. A scala di edificio gli spazi derivanti da differenti combinazioni dei moduli danno forma all'organizzazione generale delle funzioni, raggruppabili in quattro macrocategorie: sfera privata (camera e bagno), uso semiprivato giornaliero (cucina e soggiorno), attività ricreative comuni (studio, sport, ecc.) e quelle ausiliarie come lavanderia, spazi tecnici, ecc. (Vráblová, Czafík and Puškár, 2022).

Per soddisfare il requisito dell'accessibilità economica (Kim and Kim, 2016) si ricorre in molti casi alla riduzione della superficie disponibile all'interno dei moduli. La conseguente riduzione della vivibilità degli spazi interni fa sì che questo tipo di soluzione venga prevalentemente scelta per abitazioni destinate a soggiorni brevi (Kotradyova et alii, 2019;

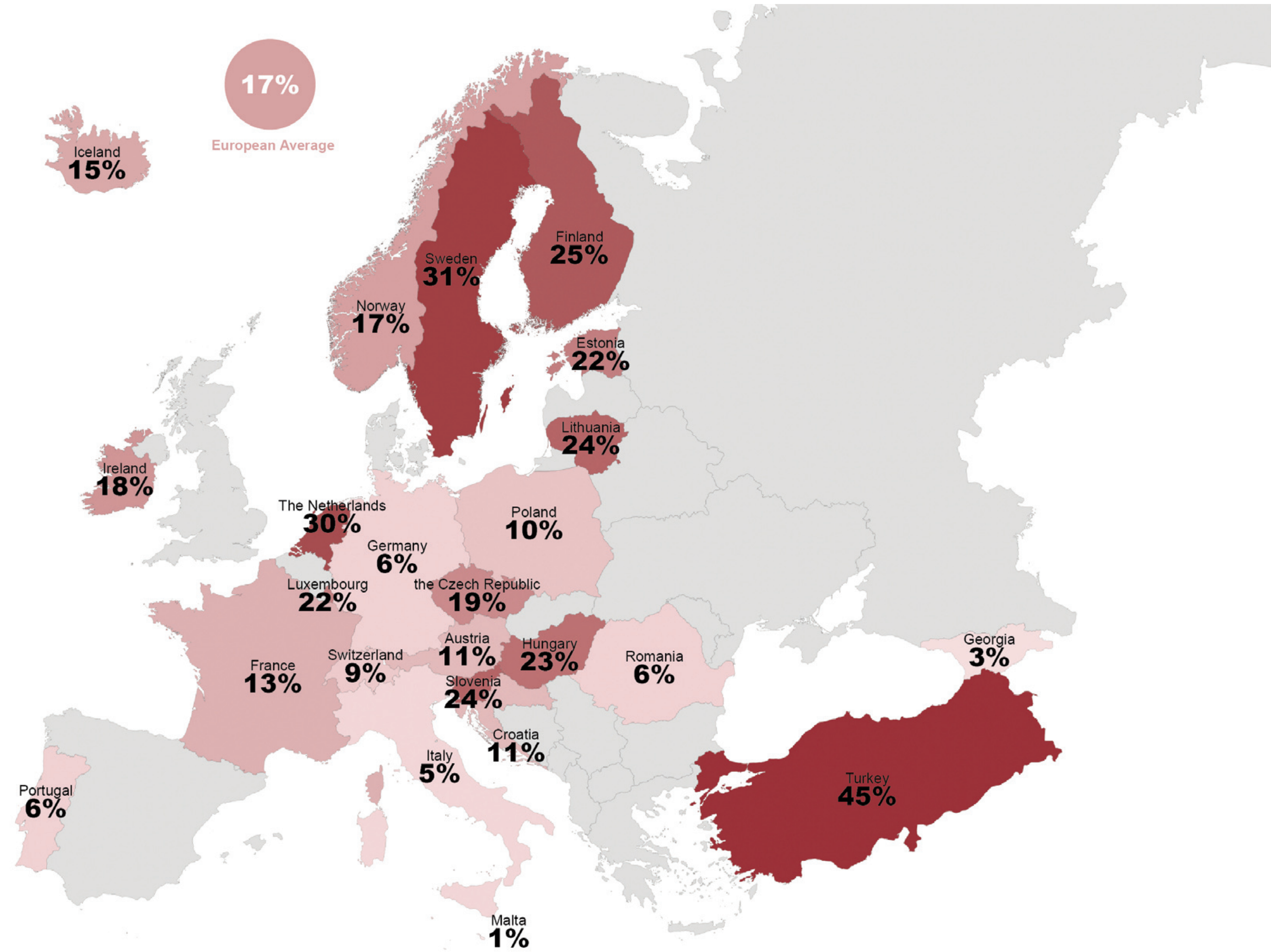


Fig. 1 | Students' housing situation: students living in student accommodations (credit: elaboration by the Authors on Eurostudent VII 2018-2021 data).

Yu et alii, 2019). La superficie dei moduli per l'abitare da studenti generalmente varia tra 17 e 56 mq (media 20/25 mq), la larghezza è solitamente compresa fra i 2,75 e 4,25 m, (media 3,40 m) e la profondità si attesta mediamente sui 6,85 m (Vráblová, Czafík and Puškár, 2022; Fig. 7); le dimensioni dei moduli sono comunque condizionate dalla normativa sui trasporti speciali, che possono variare a seconda della Nazione. La tipologia costruttiva dei moduli per lo student housing può essere ricondotta a tre macrocategorie:

– Fully Modular, in cui tutte le parti vengono assemblate e rifinite in fabbrica, mentre in cantiere si richiedono le connessioni alle fondazioni, al sottosistema portante e agli impianti a rete;

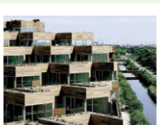
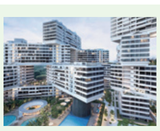
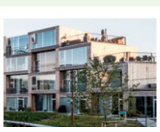
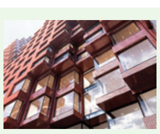
– Sectional, caratterizzata da moduli piccoli e facili da trasportare che possiedono un certo potenziale di implementazione tramite la fabbricazione digitale e l'aggiunta di componenti;

– Component, sistema a pannelli pretagliati e preingegnerizzati facilmente manovrabili e assemblabili; i componenti più piccoli richiedono tempi più lunghi di assemblaggio in loco, ma possiedono una maggiore flessibilità dal punto di vista morfo-tecno-tipologico.

Nell'ambito dei Fully Modular esiste un'ulteriore tassonomia legata alla messa in opera (Hou, Zhang and Lai, 2023; Fig. 8), per cui si hanno sistemi self-supporting (Tab. 3), core-supporting (Tab. 4) e frame-supporting (Styles et alii, 2016; Tab. 5), con una media di 8/10 piani fuori terra. I moduli abitativi per studenti generalmente soddisfano tutti i requisiti prestazionali di base (Chen et alii, 2021) e, spesso, possiedono prestazioni superiori. A sostegno dell'interesse che questa metodologia costruttiva sta suscitando presso gli operatori del settore, è possibile segnalare come negli ultimi anni la letteratura scientifica si sia fortemente consolidata, approfondendo potenzialità e limiti che i moduli abitativi modulari sono in grado di offrire (Subramanya, Kermanshachi and Rouhanizadeh, 2020; Agha et alii, 2021).

Potenzialità | I benefici più evidenti che i moduli abitativi presentano sono dovuti alla prefabbricazione e alle conseguenti modalità produttive e di messa in opera: rispetto ai sistemi costruttivi tradizionali, questa tecnica risulta più sostenibile, economica e funzionale. Il tempo necessario per completare una residenza di questo tipo è solitamente inferiore del 50-60% rispetto alla costruzione basata su tecniche tradizionali (Ferdous et alii, 2019), soprattutto perché il processo non è condizionato dalle condizioni metrologiche.

L'automazione e la digitalizzazione permettono inoltre di rispondere ai controlli di qualità di linea garantendo il prodotto finale. La prefabbricazione permette l'informatizzazione in house di tutte le prescrizioni derivanti dalle normative in ambito edilizio, sanitario, ambientale, di sicurezza, ecc. (Chen et alii, 2021). I benefici ecologici dei moduli abitativi per l'abitare da studenti sono soprattutto dovuti alla scarsa produzione di rifiuti di cantiere e all'utilizzo di tecniche costruttive a basso impatto ambientale (Mesa, Esparragoza and Maury, 2020): rispetto alle modalità costruttive tradizionali, i sistemi abitativi prefabbricati riducono la quantità di rifiuti da discarica del 70% (Jaillon, Poon and Chiang, 2011), la rumorosità delle lavorazioni di cantiere del 30-50% (Lawson, Ogden and Bergin, 2012), mentre le vibrazioni e le polveri (Ferdous et alii, 2019) risultano in linea con i principi LCA (Kamali and Hewage, 2016), creando luoghi di lavoro più sicuri e salubri (Enshassi et alii, 2019). Inoltre la ripetitività delle fasi produttive permette un controllo puntuale della quantità dei materiali e il loro riutilizzo all'interno del ciclo produttivo (Illankoon and Lu, 2020).

Year	Imagine	Project	Notes
1967		Moshe Safdie, HABITAT 67, Montrèal (CA) ©Gili Merin	Iconic architecture that takes its name from the event for which it was built, Expo 67 'Man and His World'. A housing complex (160 apartments, 12 flours), built with 354 (11,7 x 5,3 x 3 m) prefabricated, prestressed reinforced concrete 'boxes' placed in their place by a crane and held together by cables. It represents the idea of aeconomic construction for collective needs.
1971		Paul Rudolph, ORIENTAL MAXSONIC GARDENS, New Haven (USA) ©Paul Rudolph Collection, Library of Congress	The modularity of the project allows for 148 building units to be built on 4.700 sqm site area. It was the first project utilizing the 'Twentieth Century Brick'. These stacked houses consist of two blocks, one at the ground floor (living-dining-kitchen), a second at the second floor (bedrooms and baths).
1972		Marco Zanuso and Richard Sapper, MOBILE HOUSING UNIT ©Richard Sapper Archives	A flexible and mobile housing system for the exhibition 'Italy: the New Domestic Landscape' held at MoMA. This housing module, although designed as an autonomous unit, had the inherent ability to be extensible and repeatable. Its main aim was to provide a solution for potential emergency situations.
1972		Kisho Kurokawa, NAKAGIN CAPSULE TOWER, Tokyo ©Archspace	Two buildings, 11 and 13 floors, consisting of a series of cubes (capsules) stacked on each other. The 140 prefabricated modules (2.3 x 3.8 x 2.1 m) are independent of each other and are supported by the central reinforced concrete supporting structure
1982		Renzo Piano EVOLUTIVE HOUSING, Corciano (IT) ©Fondazione Renzo Piano	The apartments' architectural concept integrates the concepts of prefabrication and adaptability that Piano had been exploring since the 1960s and the experience of Laboratori di Quartiere. The goal was to create affordable housing modules, flexible and with the possibility of expanding or reducing the habitable surface over time.
1984		Piet Blom, KUBUSWONINGEN, Rotterdam (NL) ©Dirk Verwoered	The project consists of an inclined wooden cube that stands with a point on a hexagonal concrete core, where there are the entrance and the stairwell. On the lower floor are the kitchen and bathroom, on the middle floor the bedrooms and bathroom, on the top floor either the children's room or a solarium.
1984		Pierluigi Spadolini, SAPI, ©Edil.Pro. Gruppo IRI-Italstat / Archivio Eredi Pierluigi Spadolini	Sistema Abitativo di Pronto Intervento (SAPI) was one of the first Italian prefabrication experiments. Fiberglass housing modules of various sizes for emergency situation. The main objective was to have a minimum volume in the transport phase and a maximum volume in the use phase.
2003		Alejandro Aravena, QUINTA MONROY, Iquique (CL) ©Cristobal Palma / Estudio Palma	The project was supposed to secure the case for 100 families, but a budget of only $7,500 was planned. In response to this problem, it is planned to give only the first half of the house (about 40 sqm). Tenants were given the possibility of expansion up to about 58 sqm or 76 sqm for duplex.
2008		PLOT = BIG + JDS, MOUNTAIN DWELLINGS, Copenaghen (DK) ©Jacob Boserup	An opportunity to explore a new form of symbiotic urbanism when asked to design apartments next to a parking garage. The parking transforms into a podium for the building's 80 homes that form a stepped landscape, a mountain, of modular homes with gardens.
2013		OMA, Ole Scheeren, THE INTERLACE, Singapore (SG) ©Iwan Baan	Thirty-one apartment buildings, each six stories tall and identical in length, are stacked in a hexagonal arrangement around eight open courtyards. The project, of 170,000 sqm and over 1,000 residential units of various sizes, promote a sense of community, but maintaining individuality.
2022		BIG, SNEGLEHUSENE HOUSING, Aarhus (DK) ©Rasmus Hjortshøj - COAST	The project consists of two kinds of stacked modules, which are repeated to create the characteristic checkered pattern. The modular concept has made it possible to keep the simplicity in execution. The project includes a variety of residential options with sizes ranging from 50 to 150 sqm.
2022		MVRDV, RED7, Moscow (RS) ©MVRDV Status: design	Modularity offers the flexibility to create different interior shapes and layouts, both compact and spacious apartments. The overlapping of modules returns a sculptural building, allows distinctive entrances and strengthens the view of the city.

Tab. 1 | Evolution of contemporary modular housing solutions (credit: the Authors, 2023).

L'industria per la produzione di moduli abitativi appare altresì più propensa all'innovazione di processo e di prodotto risultando più sensibile ai temi dell'Industria 4.0, prediligendo una produzione automatizzata, interconnessa ed efficiente. Le costruzioni modulari possiedono un elevato grado di flessibilità tecnologica, rispondono a principi di addizione e reversibilità, rendendo possibili ampliamenti o riduzioni (aggiungendo o sottraendo moduli). Un'altra possibilità tecnologica riguarda l'adattabilità e trasformabilità, in quanto lo stesso layout del modulo può essere nel tempo modificato o adattato. Una grande flessibilità e variabilità dal punto di vista estetico e figurativo è possibile grazie a un'ampia gamma di prodotti, componenti e sistemi di finitura: ciò permette di far apparire il manufatto non come sommatoria di moduli ma simile a una architettura di tipo convenzionale (Bellini and Donadoni, 2018). Considerando che il numero di incidenti (cadute dall'alto, schiacciamento, folgorazione elettrica, ecc.) è significativamente elevato nel settore delle costruzioni (il 20% risulta mortale), la progettazione modulare si configura come una soluzione utile ad aumentare i livelli di sicurezza in cantiere (Enshassi et alii, 2019), rispetto a quelli tradizionali, riducendo i rischi dell'80% circa (Klakegg, 2013).

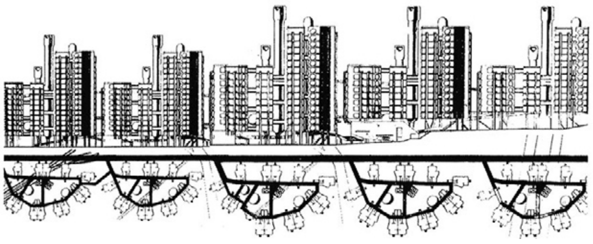
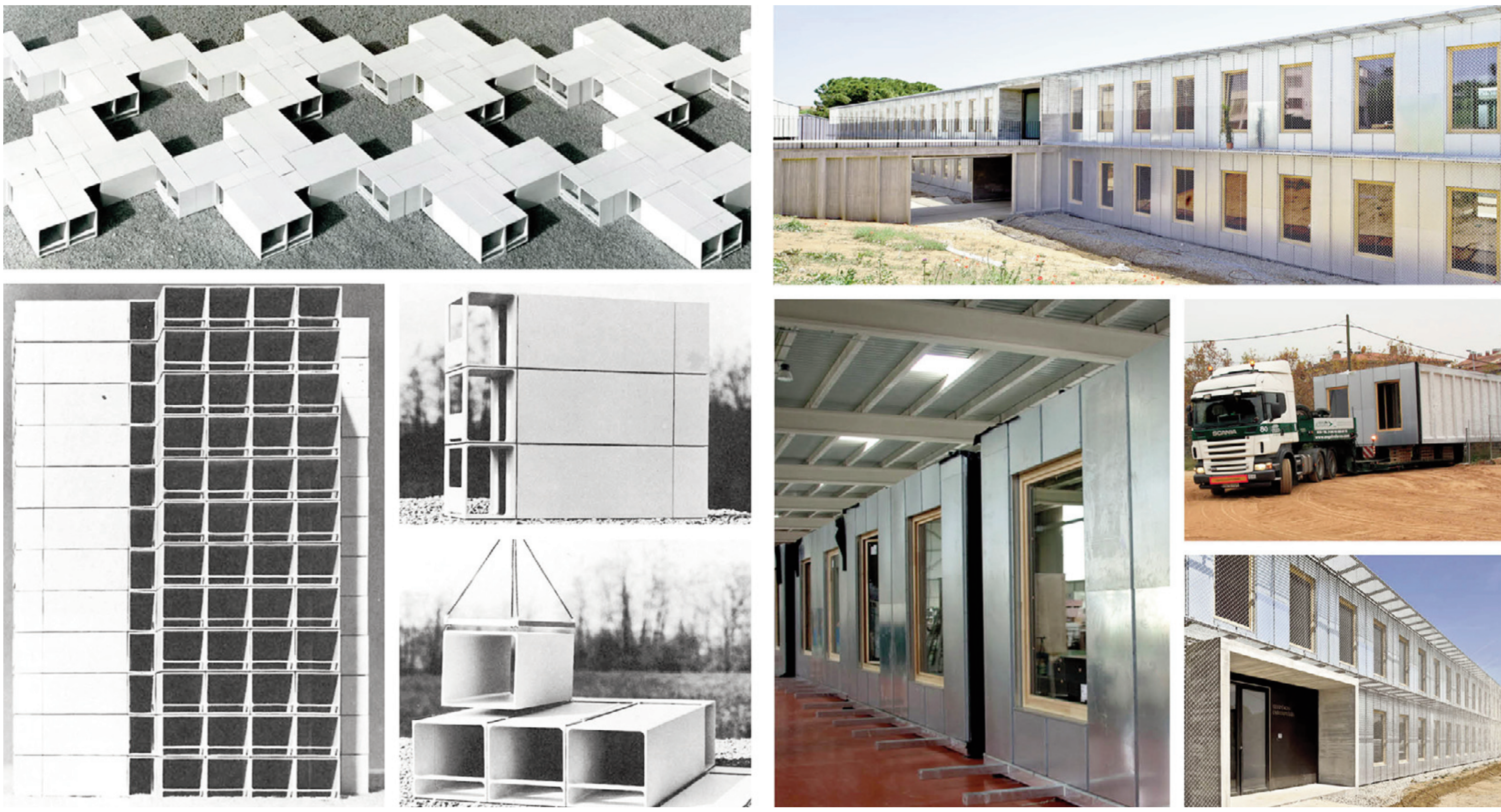
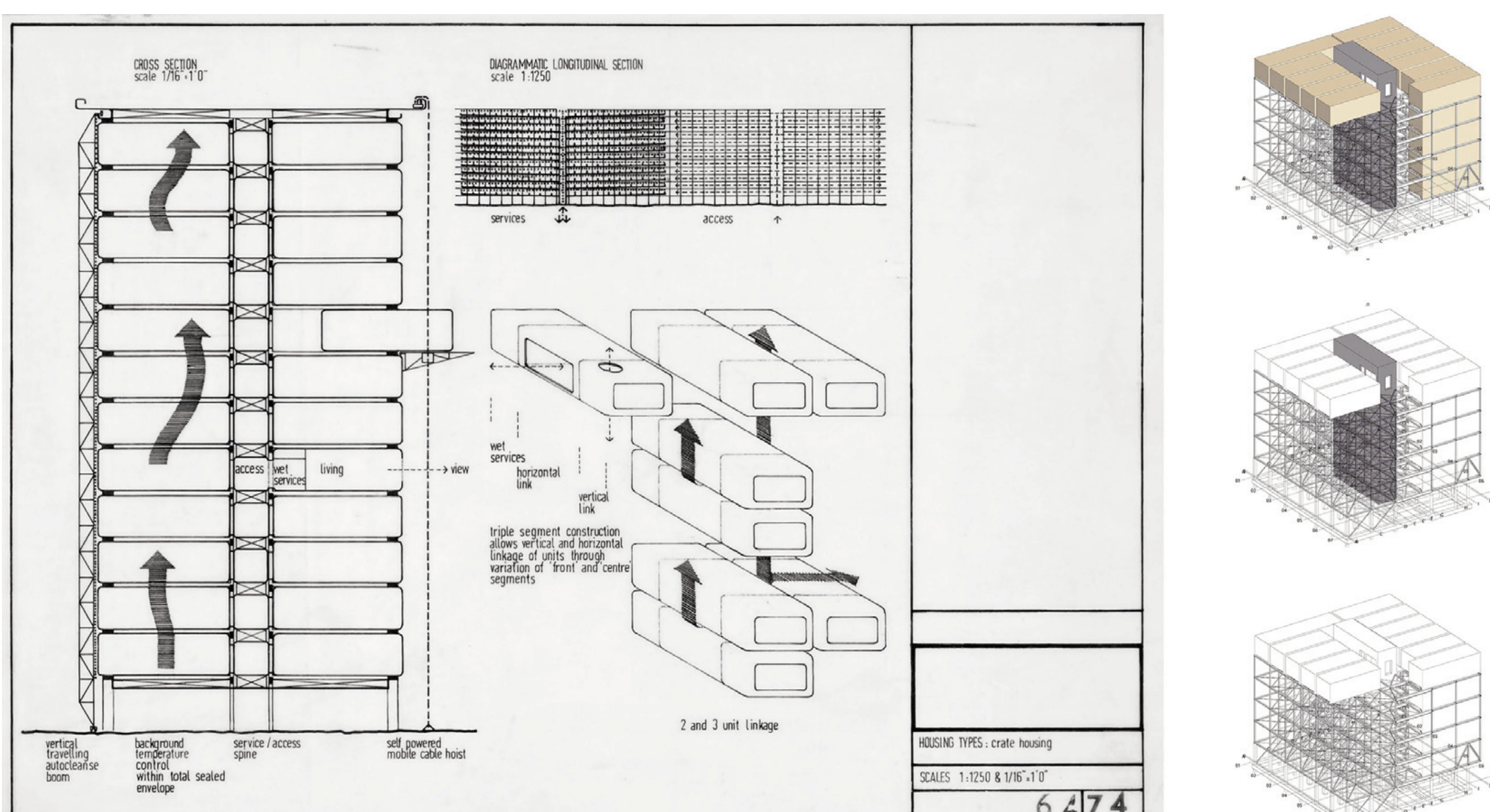


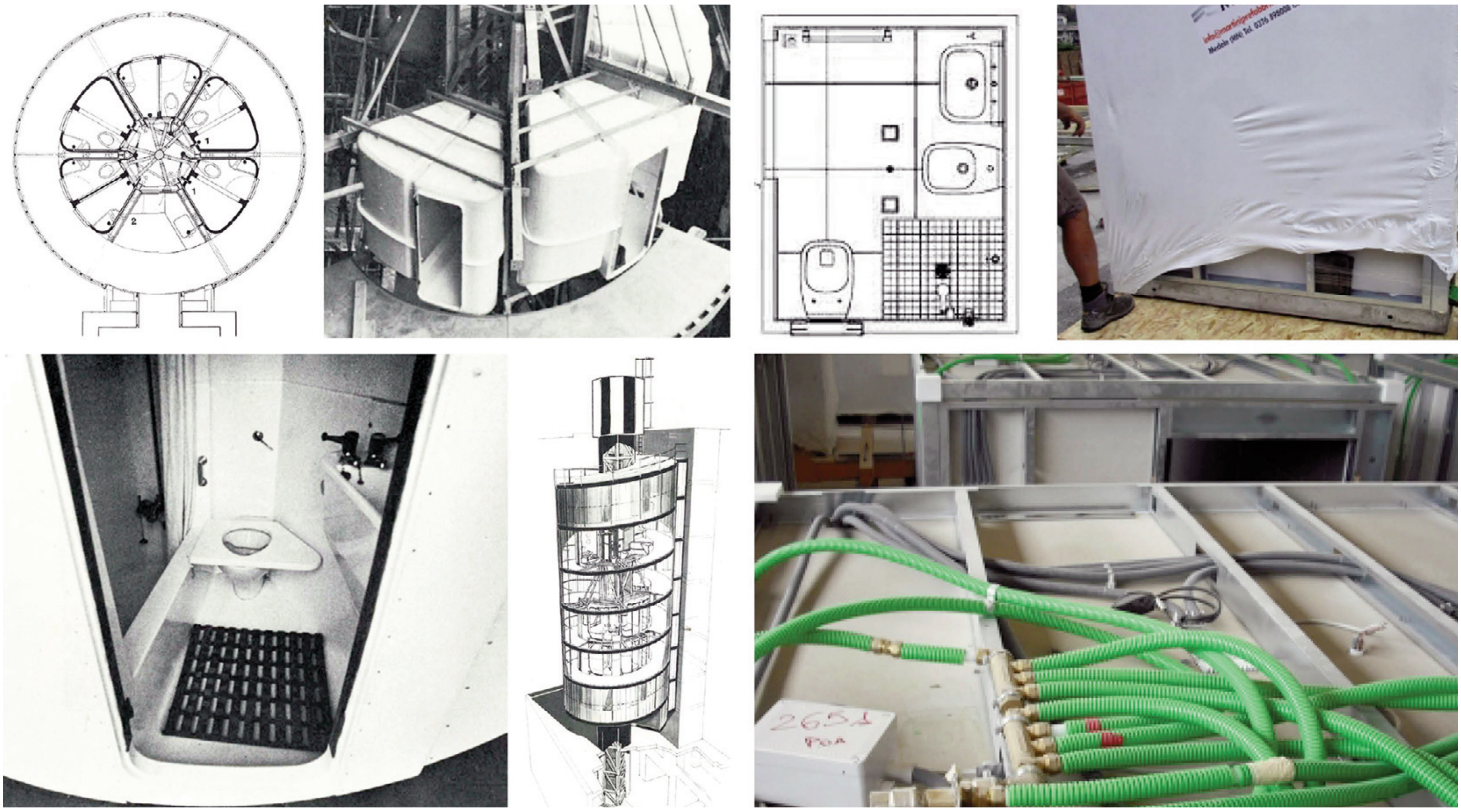
Fig. 2 | Car Body / Pressed Metal Cabin student housing project (1960), designed by Peter Cook: plan and evolution evaluation (credit: Archigram Archives, 1961).

Fig. 3 | Comparision between Raumzellenbauweise (1961), designed by Herbert Ohl and Bernd Meurer, and Student Housing Universitat Politècnica de Catalunya (2012), designed by H Arquitectes + dataAE, Sant Cugat Del Vallès (credits: Roland Fürst, HfG-Archiv / Ulmer Museum; Adrià Goula and H Arquitectes + dataAE).

Fig. 4 | Comparision between Housing types – crate housing (1964), designed by Cetric Price, and Student Housing DUWO in Delft (2009), designed by Mecanoo (credits: Cedric Price fonds, Collection Centre Canadien d'Architecture / Canadian Centre for Architecture, Montréal, 1963; Mecanoo).







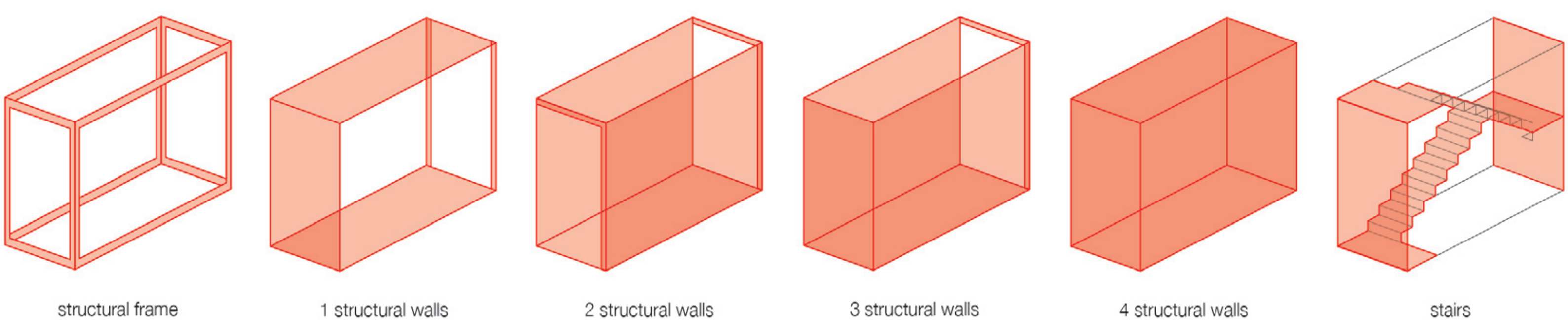


Fig. 5 | Comparision between International Students' Hostel London (1968), designed by Farrell and Grimshaw Partnership, and University Residence Mayer in Trento (2018), designed by Studio BBS (credits: Martini Prefabbricati and P. Simeone).

Fig. 6 | Structural solutions for the volumetric module (credit: the Authors, 2023).

Rispetto ai costi di realizzazione è stato dimostrato come gli edifici con moduli prefabbricati permettano risparmi del 10-25%, soprattutto in relazione all'assenza di imprevisti in corso d'opera (Alazzaz and White, 2014). A questo risparmio contribuiscono diversi fattori di processo: velocità di costruzione; riduzione degli ingombri e dei costi delle attrezzature di cantiere; impiego limitato di macchine edili; ridotto numero di lavoratori con conseguenti risparmi salariali; assenza di fornitura, trasporto e stoccaggio di altri materiali; certezza dei costi; maggiore durata del ciclo di vita; minori costi di manutenzione, ecc. Queste prerogative consentono un ritorno economico dell'investimento iniziale in tempi relativamente più veloci, un risparmio del 20% sui costi e una riduzione dei rischi d'impresa sulla programmazione che può arrivare al 50% (Salama et alii, 2017).

Limiti | Sebbene i costi di produzione dei moduli prefabbricati per la realizzazione di residenze universitarie siano inferiori, rispetto al costruito tradizionale, è sempre necessario poter disporre di un impianto di produzione organizzato su principi di ripetibilità, automazione e digitalizzazione. L'impianto deve essere pianificato sulla base di un business plan che, oltre a verificare i tempi di ritorno del consistente investimento iniziale, deve accertare l'esistenza di domanda concentrata, la disponibilità di manodopera specializzata e la possibilità d'accesso veloce ai collegamenti viari (Rahman, 2014). Fra i limiti di questo sistema costruttivo vi è la necessità di avvalersi di professionalità altamente specializzate, sia per la progettazione che per la realizzazione dei moduli.

A causa della differenza di approccio fra progettazione modulare e convenzionale possono sorgere criticità di coordinamento del processo di progettazione, produzione e assemblaggio. Un'accurata pianificazione del progetto è un requisito necessario per controllarne il risultato finale; pertanto la presenza di esperti con comprovate capacità nell'ambito della progettazione modulare è fondamentale, parimenti a quella di esperti dell'abitare da studente (Li, Shen and Xue, 2014). L'architettura modulare prefabbricata non sempre permette la realizzazione di ampi spazi comuni dedicati agli studenti a causa della sua rigidità spaziale e tipologica.

Dal punto di vista culturale gli operatori del settore edilizio spesso non riconoscono i sistemi modulari come una vera e propria tecnica costruttiva (nonostante questi sistemi riescano a soddisfare a pieno i requisiti e gli standard richiesti) e tra gli studenti persiste una certa diffidenza nei confronti di questi sistemi per la scarsa definizione estetico-figurativa (dovuta all'immagine di tecnicità, uniformità e monotonia) delle soluzioni impiegate (Vráblová, Czafík and Puškár, 2022). Si rende pertanto necessario sensibilizzare il mondo professionale, gli studenti / utenti e le Università sulle possibilità che questo sistema costruttivo può offrire.

La morfologia e la geometria dei moduli sono vincolate dalle dimensioni dei mezzi di trasporto, pertatno se il trasporto si configura come ecce-

Terms	Definition	Example
OFF-SITE PRODUCTION	Largely interchangeable terms referring to the part of the construction process that is carried out away from the building site. This can be in a factory or sometimes in specially created temporary production facilities close to the construction site (or field factories). ©Horizon North	
PREFRABRICATION (Prefabricated Building)	This is a general term for the manufacture of entire buildings or parts of buildings offsite prior to their assembly onsite. Prefabricated buildings include both portable buildings and the various types of permanent building systems. Offsite is now the more commonly used term. ©Summary	
PREASSEMBLY	The manufacture and assembly of a complex unit comprising several components prior to the unit's installation onsite. Offsite is now the more commonly used term. ©QWEB	
STANDARDISATION	The extensive use of components, methods or processes in which there is regularity, repetition and a background of successful practice. This may include standard building products, forms of contract, details, design or specifications and standard processes, procedures or techniques. ©L&G	
HYBRID BUILDING SYSTEM	A combination of volumetric and panelised systems where the high value areas (kitchen and bathroom) are typically formed from volumetric units (sometimes referred to as pods) and the rest of the structure formed from some form of framing system. ©Sterchelegroup	
MODULE (Modular Construction, Modular System, Modularisation)	More commonly, they refer to volumetric building modules where the units form the structure of the building as well as enclosing useable space. The terms are also sometimes used to describe room modules, which do not incorporate their own superstructure. ©Plant PreFrab	
POD	Prefabricated volumetric pod, fully factory finished internally complete with building services, probably not completed externally. Types of pod include bathrooms, shower rooms, office washrooms, plant rooms, kitchens. ©Surepods	
ELEMENT	Part of a building or structure that could be considered for standardisation and offsite production such as foundations, structural frame, envelope, services, internals and modular units. ©Ckark Pacific	

Tab. 2 | Some definitions of off-site construction (source: Gibb and Pendlebury, 2013).

zionale sono obbligatori permessi speciali e veicoli di accompagnamento, con un conseguente notevole aumento dei costi[1]. La costruzione modulare richiede anche un'accurata pianificazione degli aspetti logistici, come lo studio dei percorsi, verificandone ad esempio le restrizioni di percorribilità, i sottopassi, le gallerie e le curve. Una volta giunti in cantiere i moduli vengono assemblati mediante un meccanismo di sollevamento, il più delle volte una gru mobile, attività questa molto delicata che richiede particolare attenzione anche alla sicurezza degli operatori (Fig. 9).

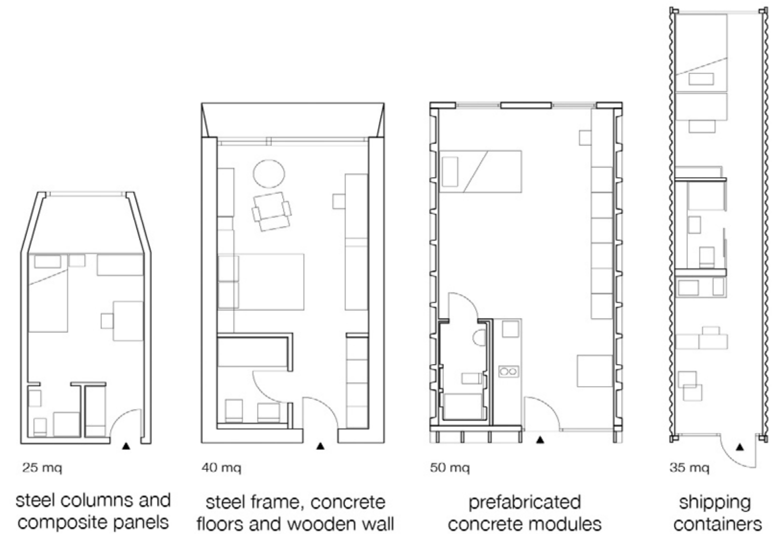
L'architettura modulare per studenti, spesso, si scontra con apparati normativi cogenti e con regolamenti edilizi e urbanistici locali che non contemplano questo tipo di architetture per soluzioni abitative a medio-lungo termine.

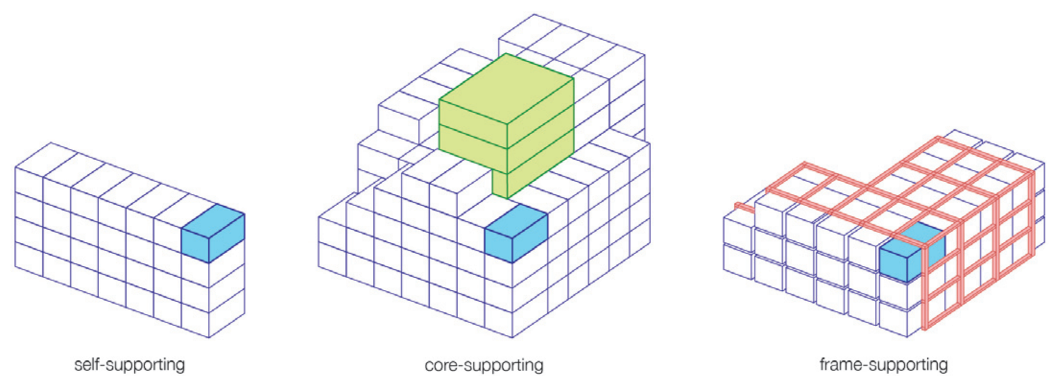
Prospettive | I moduli abitativi prefabbricati per l'ospitalità universitaria presentano generalmente più vantaggi che svantaggi (Wallace, 2021). I limiti di questo sistema possono presumibilmente essere eliminati sulla base di ulteriori ricerche e analisi, soprattutto in ambiti specifici come quello dell'abitare da studenti. Tuttavia non è possibile stabilire a priori se l'uso della costruzione modulare risulti più appropriato rispetto alle tecniche costruttive convenzionali. Ogni intervento deve essere considerato a sé e valutato all'interno del contesto di riferimento; parimenti ogni scelta deve essere guidata sia da un appropriato processo decisionale che sappia valutare capacità progettuali, know-how tecnologico e capacità tecniche sia da una oculata valutazione di limiti e opportunità che l'impiego di una tecnica comporta. Nonostante ciò è possibile riconoscere la grande potenzialità dei sistemi abitativi modulari prefabbricati, soprattutto se relazionati a specifiche emergenze abitative, come quella delle residenze universitarie nel nostro Paese.

La stringente attualità del tema e le prerogative della progettazione modulare concorrono a ipotizzare che la necessità di implementare in breve tempo il numero dei posti letto – secondo criteri di affidabilità ed efficienza, razionalizzazione dell'iter realizzativo, controllo dei costi e dei tempi di costruzione, riduzione degli scarti di lavorazione e raggiungimento di adeguati parametri di efficienza energetica e decarbonizzazione – contribuisce all'opportunità di considerare questa opzione.

Nell'ambito poi della gestione e implementazione della progettazione il BIM, ormai obbligatorio per gli appalti dei lavori pubblici, consente di avvalersi di una matrice ragionata e relazionale di attività e compiti guida che possono definire anche nella progettazione modulare l'analisi pratica dei limiti e delle opportunità (Qin and Yao, 2020;), grazie a un software che, senza limitare la capacità creativa dell'architetto, può aumentare l'efficienza della progettazione e un corretto impiego delle risorse.

L'architettura modulare prefabbricata può essere quindi proposta come un modo innovativo per controllare l'ideazione, la costruzione e la gestione delle residenze universitarie, senza però dimenticare che i valori culturali e simbolici che questa architettura universitaria rappresenta, devono essere sostenuti dal «[…] mettere in conto che i problemi dell'istruzione non possano compiersi senza un'architettura educatrice» (Rogers, 1947, p. 1).





Figg. 7, 8 | Typical module sizes; Assembly method of modules (credits: the Authors, 2023).

In a university education system that aims to be competitive internationally, student residences represent an unavoidable social infrastructure to support mobility. In addition to facilitating the reduction of education costs, in which the 'accommodation' has a significant impact (Hauschildt et alii, 2021), these infrastructures appear, from a sociological point of view, to be the most appropriate solutions to promote individual independence, experience the community dimension, encourage, and foster the relationships between heterogeneous groups of people (with different origins and cultures). Nevertheless, the shortage of student accommodation remains a limit that thousands of off-campus university students are dealing with. In Italy, only 5% of students live in this typology of housing (Fig. 1; Hauschildt et alii, 2021).

To address this housing issue, it is possible to use modular off-site housing systems, an efficient and versatile construction solution widely used in emergency housing and recently in the student housing sector. In these cases, the design module is transformed to create expressiveness. The former could be capable of governing various aspects of process and product, using the principles of industrialisation and prefabrication, such as construction simplicity and speed, performance levels quality, compliance with environmental and anti-seismic regulations, strict control of execution times, etc. (Dörries and Zahradnik, 2019; Ermolli and Galluccio, 2019; Scalisi and Sposito, 2021).

Off-site Modular Construction enables the design of buildings with different scales of complexity, where the standard cell is configured as a «[…] three-dimensional or volumetric unit that is assembled in a factory and delivered to a construction site as the main structural element of a building» (Lawson, Ogden and Goodier, 2014, p. 1). This construction technique has relatively distant roots in time, marked by interesting experiments that, in many situations, seem to possess recursive characteristics.

Prodromes | On a theoretical level, any consideration of the concept of module presupposes a comparison with the studies and research of Carlo Giulio Argan (1965), collected in Progetto e Destino. This book investigated the module's evolution, adjustments, synthesis, and cultural expression in the disciplinary context. The connotative nature of this research has allowed to define the assumption of 'module-object' as the conceptual principle of construction and of 'module-measure', an abstract dimensional entity that, in architecture, establishes qualitative or quantitative relationships between the parts.

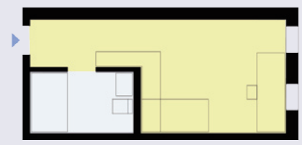
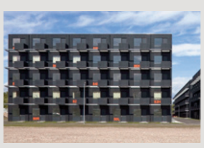
In evolutionary terms, the 'module-object', a compendium of the concepts of 'compositional module', 'constructive module' and 'typological module', manifests itself throughout the history of architecture in multiple situations: in Fuller's reticular structures, in Utzon's additional modularity, in Wachsmann's experimental industrial applications, in Habraken's concept of Open Building, in Kurokawa's prototypes, as well as in Spadolini's Sistema Abitativo di Pronto Impiego (lit. Emergency Housing System; Tab. 1). In addition to exploring the potential of the module in the context of social emergencies related to housing, this evolutionary framework also includes the experimental experiences of W. Gropius and J. Prouvè, who expanded the scientific debate around the paradigm of functional, spatial, and technological flexibility.

In all these cases, according to Argan, the 'module-object' is transformed into an 'ideational principle', becoming 'the basic fact of construction'. Unlike the compositional module (a virtual dimensional entity useful in establishing quantitative or qualitative metric relationships between parts), the object-module allows architecture to introduce a paradigm shift, making a non-physical entity merge with an industrial product.

Since the 1960s, these assumptions have been applied to university residences, yielding experiments with innovative solutions, paradigmatic 'archetypes' and involuntary models even for the most recent solutions.

This process can only be understood by referring to the cultural and disciplinary transformations proposed by Rationalism (1930s) for the first time when the topic of housing was reduced to a purely functional issue. Additionally, reconsidering the user's role as an active part in the project changed the relationship between those who design and those who produce, imagining a mass production also open to architecture. In this way, the project no longer belongs to an elite but to the capacity of those who use it. To respond to their needs, the users can interpret, modify, and regenerate the project based on their creativity.

The repercussions on the university housing project of this new conceptual framework are also due to the Archigram and their manifest interest in new technologies and increasing industrialisation. In 1960, Peter Cook, a leading figure of Archigram, designed the Car Body / Pressed Metal

SELF-SUPPORTING							
Year	**Imagine**	**Project**	**Main Material of Structural Support**	**Size**	**Main Layout**	**Storey above ground**	**Compositional Scheme**
2019		WilkinsonEyre, DYSON INSTITUTE, Malmesbury (UK) ©Peter Landers	Cross-Laminate Timber (CLT) construction	30 sqm		3	no-visible
2017		Sauerbruch Hutton, 'WOODIE' STUDENT DORMITORY, Hamburg (DE) ©Jan Bitter	wooden prefabricated modules	19 sqm		7	semi-visible
2011		Harquitectes + Data AE, STUDENT HOUSING, Sant Cugat del Vallès (ES) ©Adrià Goula	prefabricated concrete modules	55 sqm		2	semi-visible
2010		Fact Architects, ZUIDERZEEWEG, Amsterdam (NL) ©Fact Architects	steel frame, wood-based panels	30 sqm		5	semi-visible

Tab. 3 | Structural solutions for Student Housing modular buildings: self-supporting (credit: the Authors, 2023).

Cabin, a mass-produced pop house for students realised with plastic and metal modules (Fig. 2). This solution overcame the spatial and construction rigidity of typical student housing solution for the time. It represented an unusual vision with references to science fiction literature and cybernetics, a literal transcription of the enthusiasm for the automotive sector.

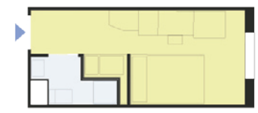
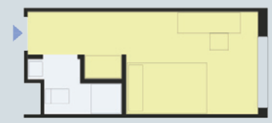
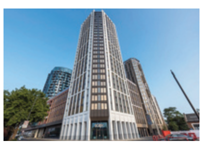
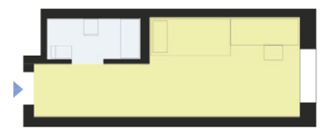
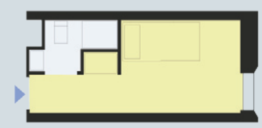
In the same period, Herbert Ohl, a professor at the Institute of Industrialised Building in Ulm, designed the Raumzellenbauweise system (Short, 2021), composed of three-dimensional modular housing units (Fig. 3) in extruded reinforced concrete (6.00 x 2.69 x 2.74 m). Assembled by bolting at the corners, this system allowed multiple morphological and spatial configurations. It was based on a systemic approach, with attention to environmental sustainability, optimisation of materials, simplification and speed of construction, low-cost / high-quality, reversibility of components, their life cycle, etc. These paradigms anticipated, after a few decades, protocols for environmental certification.

In 1964, the technocratic Cedric Price presented Potteries Thinkbelt, a project with a robust innovative charge that became an irreplaceable source of inspiration for many of the most recent modular housing solutions for students (Vráblová, Czafík and Puškár, 2022; Fig. 4). The Thinkbelt proposes a language that explicitly alludes to the aesthetics of the industrial and mechanical world (Lobsinger, 2000), proposing a university on rails, where 20,000 people could live in combinable, relocatable flexible, adaptable, relocatable, differentiated capsule ('sprawl', 'capsule', 'crate' and 'battery housing'). Price writes, «[…] while students are at present one of the most mobile social groups of technologically advanced societies, the nature of their own particular production plants – schools, colleges and universities, is static, introspective, parochial, inflexible and not very useful» (Price, 1970, p. 13).

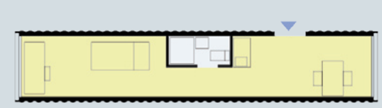
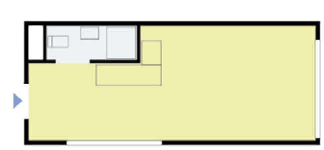
In experimental student housing evolution, the 'module-object' finds application in the form of technical elements, bathrooms, kitchens, etc., also in the context of recovering the built environment. Around the 1970s, the architects Terry Farrell & Nicholas Grimshaw Partnership proposed for the International Students Club the use of pre-designed, pre-engineered, and prefabricated modular components in the recovery of a series of Victorian-era Terrace Houses (Fig. 5). The project was meant to add a Server Tower to existing structure with a spiral ramp that served a series of modular toilets services composed of six different quarters of pre-finished reinforced plastic modules. This system exemplified, in an almost didactic way, the potential of modular design applied to the existing building.

From this albeit synthetic overview, student housing has historically been and continues to be, a field of experimentation not only typological but also technological. On the construction level, the aggregations of the housing modules can be various: by putting next to each other, overlapping and juxtaposition, with component solutions such as bifacial, partially bifacial, angular support, non-load-bearing, etc. (Subramanya, Kermanshachi and Rouhanizadeh, 2020; Fig. 6). Moreover, the structural system could be punctiform, linear or box-shaped, self-supporting or not, and made of reinforced concrete, steel or wood (Tab. 2). Each patent has specific performance that cannot be generalised, although the self-supporting structure with dry finishes prevails. The bedroom and bathroom usually define the functional nature of the interior of the modules. The former, if naturally ventilated, is located near the entrance, and the housing unit is usually accessed through a linear connectivity (landing), with a consequent contraction of privacy level. In addition to the bedroom and bathroom, there are other spaces, such as a kitchenette, a micro-living room, a balcony, etc.; in this case, the module, in general, has a longitudinal development, where the position of the bathroom allows for the division of the layout into two distinct functional zones. At the building scale, the spaces result from the different combinations of modules that shape the general organisation of functions. These functions can be classified into four macro-categories: private sphere (bedroom and bathroom), semi-private daily use (kitchen and living room), everyday recreational activities (study, sports, etc.) and auxiliary activities such as laundry, technical spaces, etc. (Vráblová, Czafík and Puškár, 2022).

To meet the requirement of affordability (Kim and Kim, 2016), in many cases, the available surface area within the modules is reduced, so this type of accommodation is usually chosen for short-stays (Kotradyova et alii, 2019; Yu et alii, 2019). The surface area of the modules for student residences generally swings between 17 and 56 square meters (average 20/25 square meters), the width between 2.75 and 4.25 m (average 3.40 m) and the depth is on average 6.85 m (Vráblová, Czafík and Puškár, 2022; Fig. 7). The size, on the other hand, is conditioned by the regulations related to special transports, which may change depending on country police.

CORE-SUPPORTING							
Year	**Imagine**	**Project**	**Main Material of Structural Support**	**Size**	**Main Layout**	**Storey above ground**	**Compositional Scheme**
2021		Jtp Architects, LEWISHAM EXCHANGE, London (UK) ©Benedict Luxmoore & JTP *student and residential	reinforced concrete	20 sqm		20/35	semi-visible
2019		HTA Design, FELDA HOUSE, Wembley London (UK) ©Vision Modular Systems	reinforced concrete	20 sqm		19	no-visible
2017		HTA Design, APEX HOUSE, Wembley (UK) ©Vision Modular Systems	reinforced concrete	25 sqm		29	semi-visible
2011		O'Connell East Architects,VICTORIA HALL STUDENT ACCOMMODATION, Wembley (UK) ©Flatshare Ltd.	reinforced concrete	15 sqm		19	no-visible

Tab. 4 | Structural solutions for Student Housing modular buildings: core-supporting (credit: the Authors, 2023).

FRAME-SUPPORTING							
Year	**Imagine**	**Project**	**Main Material of Structural Support**	**Size**	**Main Layout**	**Storey above ground**	**Compositional Scheme**
2017		Holzer Kobler Architekturen, FRANKIE & JOHNNY STUDENT HOUSING, Berlin (DE) ©Jan Bitter	shipping containers	26 sqm		4	visible
2010		Atelier Cattani, CITÉ A DOCKS, Le Havre (FR) ©Vincent Fillon	shipping containers	24 sqm		4	visible
2009		Mecanoo Arhitecten, STUDENT HOUSING DUWO, Delft (NL) ©Christian Richters	steel frame	21 sqm		6	no-visible
2005		HDVN Architecten, QUBIC, Amsterdam (NL) ©Qubic luuk kramer	flat structural planes	24 sqm		2	semi-visible

Tab. 5 | Structural solutions for Student Housing modular buildings: frame-supporting (credit: the Authors, 2023).

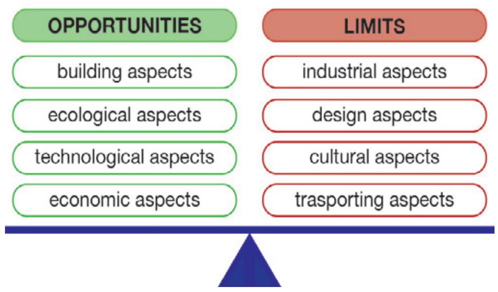


Fig. 9 | Qualitative evaluation of modular housing systems for Student Housing (credit: the Authors, 2023).

The construction typology of the student residence modules can be classified into three macro-categories:
– Fully Modular, in which all the parts are assembled and finished in the factory, while the connections to the foundations, the load-bearing subsystem and the network systems are required on site;
– Sectional, characterised by small, easy-to-transport modules that have some implementation potential through digital fabrication and component addition;
– Component, a system of pre-cut and pre-engineered panels that are easy to manoeuvre and assemble; smaller components require longer assembly times on-site, but have greater flexibility from a morpho-techno-typological standpoint.

Within the Fully Modular typology, there is a further taxonomy related to implementation (Hou, Zhang and Lai, 2023; Fig. 8), for which there are self-supporting (Tab. 3), core-supporting (Tab. 4), frame-supporting systems (Styles et alii, 2016; Tab. 5), with an average of 8/10 floors.

The modules for student residences generally meet all the basic performance requirements (Chen et alii, 2021), even higher than those of traditional buildings. In support of the interest that this construction solution is arousing among operators in the sector, in recent years, the scientific literature has been firmly consolidated, deepening the potential and limits that modular housing solutions can offer (Subramanya, Kermanshachi and Rouhanizadeh, 2020; Agha et alii, 2021).

The Potentiality | The most evident benefits that housing module units present are due to prefabrication and the consequent production and installation methods. This technique is more sustainable, economical, and functional than traditional construction systems. The time required to complete a university residence using modules is usually 50-60% shorter than the conventional construction techniques (Ferdous et alii, 2019), mainly because metrological conditions do not condition the process.

Nowadays, automation and digitalisation also make it possible to respond to line quality controls while guaranteeing the final product. Moreover, prefabrication allows for the punctual computerised in-house control of all requirements deriving from the mandatory regulations in the construction, health, safety, environmental fields, etc. (Chen et alii, 2021). The ecological benefits of housing modules for student residences are mainly due to the low production of waste and the use of construction techniques with low environmental impact (Mesa, Esparragoza and Maury, 2020). Compared to traditional construction methods, off-site housing systems reduce the amount of landfills waste by 70% (Jaillon, Poon and Chiang, 2011) and minimise construction noise by 30-50% (Lawson, Ogden and Bergin, 2012), vibrations and dust (Ferdous et alii, 2019); additionally, they are in line with LCA principles (Kamali and Hewage, 2016) and create safer and healthier workplaces (Enshassi et alii, 2019). Furthermore, the repetitiveness of the production phases allows for precise control of the quantity of materials and their reuse within the production cycle (Illankoon and Lu, 2020).

The industry of housing modules is also more inclined towards process and product innovation, being more sensitive to Industry 4.0 issues, favouring automated, interconnected, and efficient production. Modular constructions have a high degree of technological flexibility and respond to the principles of addition and reversibility, making expansions or reductions possible by adding or subtracting modules. Another technological possibility concerns adaptability and transformability, as the same module layout can be modified or adapted. From an aesthetic and figurative standpoint, excellent flexibility and variability are possible thanks to a wide range of products, components, and finishing systems. These factors allow the building to appear more similar to conventional architecture and to not an aggregation of modules (Bellini and Donadoni, 2018). Considering that the number of accidents (falls from heights, crushing, electric electrocution, etc.) is significantly high in the construction sector (20% is fatal), modular design is a valuable solution to increase safety levels on site (Enshassi et alii, 2019), by reducing risks by about 80% (Klakegg, 2013).

Regarding construction costs, it has been demonstrated that buildings with prefabricated modules allow savings of 10-25%, especially concerning the absence of unforeseen events during the construction process (Alazzaz and White, 2014). This aspect could be a crucial aspect in the design of university residences. Several process factors contribute to these savings: construction speed, reduction of the overall dimensions and costs of construction equipment, limited use of construction machinery, reduced number of workers with consequent wage savings, supply absence, transport and storage of other materials, price certainty, longer life cycle, lower maintenance costs, etc. These prerogatives allow for a faster economic return on the initial investment, a 20% cost saving, and a reduction in business risks in programming that can reach 50% (Salama et alii, 2017).

Limits | Although the production costs of prefabricated modules for the construction of university residences are lower compared to traditional buildings upstream, it is always necessary to have a production plant organised based on the principles of repeatability, automation, and digitalisation. The process must be scheduled following a business plan: verify the payback periods of the substantial initial investment, the existence of concentrated demand, the availability of specialised labour, and the possibility of fast access to road connections (Rahman, 2014). Among the limitations of this construction system, highly technical professionals are necessary for the design and construction of the modules.

Due to the difference in the approach between modular and conventional design, critical issues can arise in coordinating the design, production, and assembly process. Accurate project planning is an essential requirement to control the final result. The experts with proven skills in the field of modular design are crucial, as well as those specialising in student housing (Li, Shen and Xue, 2014). Prefabricated modular architecture only sometimes allows adequate attention to be given to common areas dedicated to students due to the typological rigidity of this construction system.

From a cultural point of view, operators often do not recognise modular systems as an actual construction technique. Despite these systems can fully meet the needed requirements and standards, among students, there is still a certain distrust of these systems due to the lack of aesthetic-figurative definition, due to the image of technicality, uniformity and monotony (Vráblová, Czafík and Puškár, 2022). Therefore, it is necessary to raise awareness among the professional world, students / users and universities about this construction system's possibilities.

Once prefabricated, the modules must reach the construction site. Therefore, their dimensions are constrained by the maximum capacity of the means of transport, often involving exceptional transport, for which special permits and accompanying vehicles are mandatory, with a consequent significant increase in costs[1]. Modular construction requires careful planning of logistical aspects, such as studying routes (verifying practicability restrictions, underpasses, tunnels, and curves). This phase requires particular attention from the operators' safety point of view (Fig. 9).

Modular architecture for students often clashes with mandatory regulatory apparatuses, local building codes, and urban planning regulations that consider something other than this type of architecture for medium-long-term housing solutions.

Perspective | Prefabricated housing modules for university hospitality generally present more advantages than disadvantages (Wallace, 2021). The limitations of this system can be eliminated by further research and analysis, especially in specific areas such as student housing. However, it is impossible to determine in advance whether modular construction is more appropriate than conventional construction techniques. Each intervention must be considered and evaluated within the reference context. Likewise, every choice must be guided by a proper decision-making process that can evaluate design skills, technological know-how, technical skills, and the limits and opportunities a technique entails. Despite this, it is possible to recognise the great potential of prefabricated modular housing systems in our country, especially if related to specific housing emergencies, such as university residences.

The relevance of the topic and the prerogatives of modular design contribute to the hypothesis to rapidly increase the number of beds, according to criteria of reliability and efficiency, rationalisation of the construction process, control of costs and construction times, reduction of processing waste and achievement of adequate energy efficiency and decarbonisation parameters contribute to the opportunity to consider this option. In the context of design management and implementation, BIM, a mandatory tool in public work that, without limiting the architect's creative capacity, can increase design efficiency and the correct use of resources, allows the use of a reasoned and relational matrix of guiding activities and tasks, which can also define the practical analysis of limits and opportunities in modular design (Qin and Yao, 2020). Therefore, prefabricated modular architecture can be proposed as an innovative way to control university residences' design, construction and management without forgetting the cultural and symbolic values represented by this architecture and that education problems can only be solved with educational architecture (Rogers, 1947).

Notes

1) In the Italian Highway Code (Codice della Strada, art. 61), exceptional transport is considered when the vehicle's width, including its load, exceeds 2.55 m., the height 4 m. and the length 12 m.

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