Chapter 27
Sharing Innovation. The Acceptability of Off-site Industrialized Systems for Housing

Gianluca Pozzi, Giulia Vignati, and Elisabetta Ginelli

Abstract From the sixties, innovation and industrialization have been a returning mantra for the construction sector at every new building cycle passage after an economic crisis, as a tool of overcoming difficulties. This positivism has always been disregarded, especially for housing and for Italy. To avoid this dynamic recurrence even in the current ecological transition passage, research must provide, in parallel with innovative products and techniques, innovative cultural approaches so that extraordinary products and techniques can be accepted by the market, demonstrating how the synergy between them leads to a high added value for sustainable quality of living. Most of the actors (from designers to builders and maintainers) agree that innovative systems, especially industrialized off-site, are more sustainable, especially today when sustainability and resilience are the core of the construction sector; despite this, these systems are struggling to spread. This contribution focuses on acceptability and decision-making processes that lead to innovative choices, identifying the innovation of the functional, social and economic management of the buildings as the "missing ring" for housing. This acceptability has certainly increased today because of new form of "atypical" living, such as senior/student and temporary housing and co-living, which contribute to intensifying the demand of "industrialized", flexible, affordable and reliable houses. Technological innovation, in fact, actives only if technical innovation is combined with strategies and new approaches in organization, marketing and after-sales services focused on sharing and participation. Through an example of a realized off-site transformable residential building and case studies of new form of management, this contribution proposes innovation perspectives capable of overcoming design and decision-making obstacles to the spread of off-site systems, also identifying in the institutional sustainability one of the cores of this subject.

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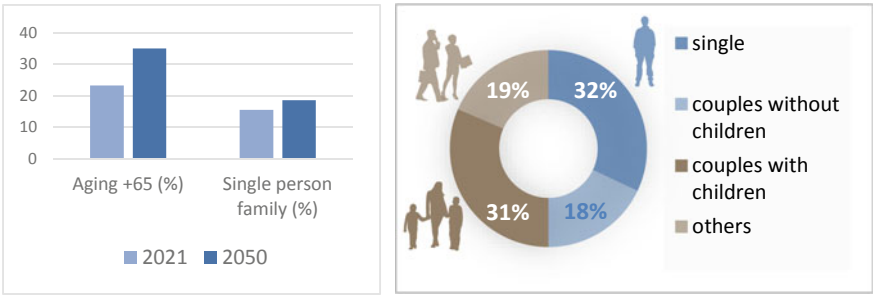
27.1 Building Cycles and Innovation: An Introduction

The contemporary Italian construction market has just entered the 7th cycle (CRESME 2020) and, like every moment of "rebound" after a decline, is characterized by a positive growth, also driven by the incentives of the PNRR. This beginning is also marked by proposals and research for the innovation of the construction sector which is, especially in Italy, radically and historically backward compared to industry and manufacturing. However, in all the turns of the cycle, the conditions so that research and constructive experimentation could effectively disseminate have never been realized in a sufficient scale to make a qualitative leap and really affect the widespread market. For this to happen, in fact, it is necessary that three conditions overlap simultaneously (Lehmann and Fitzgerald 2013; Losasso 2010; Lu et al. 2018; Russo Ermolli 2007). The first condition is technical innovations able of improving the quality and sustainability (not least economic) of constructions. The second is the political will to drive and support adequate building innovation. The third is the thrust of the market that must accept innovation and political/social demands.

27.2 Innovation for Today Housing

The construction sector is in strong evolution, and new trends are emerging in the housing market, in terms of performance, living space forms of use, costs and turnover that involve a rethinking in construction practice. New increasing segments of the population are highlighted (Graph 27.1) (CDP Cassa Depositi e prestiti 2018): young people, not numerous but with a high dynamism, and the elderly, in great increasing number. Especially for these categories, the management of the house is crucial, privileging the idea of "house as a service", with a dynamic similar to hotels management. To satisfy these demands,[1] the market requires more fluid conditions (Bergan et al. 2020). This need can be satisfied by the innovation of construction systems but also by new management models and by procedures that support their intrinsically value.

[1] Mobility of population between 18 and 35: in 2017 1.36 million people were subject to residential transfer within national borders for work (CDP 2018).



Graph 27.1 (left) Population evolution for Italy. Elaboration from ISTAT official data 2021. (right) Households composition in major cities. Elaboration from ANCE (2019)

27.2.1 The Advantages of IBS

The contemporary scientific literature (Table 27.1) and many international reports[2] clearly assert that Industrialized Building Systems (IBS[3]), especially dry techniques, significantly contribute to the sustainability of construction systems, including residential. Below is highlighted only a summary of the main advantages derived from the international literature, delegating to any future research a broader articulation and referring to Pozzi (2021) for an exhaustive treatment of the topic.

27.2.2 The Obstacles for IBS

Alongside the advantages, the same scientific literature and the proven modest diffusion clearly highlight the factors that limit the acceptance and growth of IBS. The real crux of the problem lies in the actor who makes the choice of the system to be used (Goodier and Gibb 2005) and the limiting factors can be divided, depending on the decision-maker, into factors of the client, the builder and the designer.

The **client**[4] very often has an inadequate and fragmented knowledge of systems and a scarce ability to perceive the added value of the innovative solutions, linked more to individual perceptions than to systemic market research. In addition, the client fears the possible serial nature of the industry as a customization difficulty (Boafo et al. 2016) and believes that the need to anticipate all decisions is an insurmountable obstacle (Elnaas 2014).

[2] www.freedoniagroup.com; www.fortunebusinessinsights.com/industry-reports/modular-construction-market-101662; www.grandviewresearch.com/industry-analysis/modular-construction-market; www.alliedmarketresearch.com/precast-construction-market; www.rolandberger.com/publications/publication_pdf/roland_berger_prefabricated_housing_market_3.pdf (visited on 08/03/2022).

[3] Here defined as "Off-site building construction system with high level of replicability".

[4] i.e. investors and users.

Table 27.1 Main advantages of IBS in relation to the three dimensions of sustainability, from international literature

Sustainability	Advantage	Performative advantage	Source
Environmental	Reduction of energy consumption and waste	– Lower environmental impact – Reduction of raw materials	Elnaas (2014), Jaillon and Poon (2008)
	Reduction of pollution in the production phase	– Lower environmental impact of the site	Elnaas (2014), Jaillon and Poon (2008), Jiang et al. (2018), Tam et al. (2007)
	Reduction of the overall CO_2 of the building	– Lower environmental impact – Lower carbon footprint	Elnaas (2014), Goodier and Gibb (2005)
	Greater dismantling and reversibility of the building	– Extension of the useful life – Lower environmental impact	Benros and Duarte (2009), Noguchi and Hernàndez-Velasco (2005)
Economic	Reduction of construction costs, with the same performance	– Cost-effectiveness	Jaillon and Poon (2008), Jiang et al. (2018), Goodier and Gibb (2007), Haas et al. (2000), Housing Communities and Local Government Committee (2019)
	Reduction of production times	– Cost-effectiveness	
	Triggering economies of scale, especially in modular and serial projects	– Cost-effectiveness – Productivity	Benros and Duarte (2009), Noguchi and Hernàndez-Velasco (2005)
	Faster construction improves financial performances	– Profitability – Enhancement	Elnaas (2014)
	Greater control over the quality of the work	– Quality – Reliability – Continuity of performance	Jaillon and Poon (2008), Jiang et al. (2018), Goodier and Gibb (2005)
Social	Greater safety for workers	– Safety	Elnaas (2014), Jaillon and Poon (2008), Jiang et al. (2018)
	Increased speed in housing production	– Productivity	Elnaas (2014), Švajlenka et al. (2017)
	Less inconvenience on site	– Safety – Productivity	Elnaas (2014)
	Shorter duration of the site	– Lower environmental impact	

(continued)

Table 27.1 (continued)

Sustainability	Advantage	Performative advantage	Source
	Greater maintainability	– Facilitated management – Facilitated maintainability – Durability	Luther et al. (2007)

The **manufacturing**[5] world is reluctant to accept IBS, above all because they require considerable investments of time and money in design, prototyping, for machinery production and for the stock of components (Elnaas 2014). Furthermore, for small to medium size builders, it would be impossible to realize advanced systems on their own, but they should externalize them, thus reducing their profit margins (Jiang et al. 2018; Chao et al. 2015). In addition, IBS has a fixed place of production and the costs of carrying out the work are directly linked to the distance from the construction site (Elnaas 2014), thus restricting the possible catchment area of the company. Furthermore, IBS could have a disconnection between production times (which tend to be continuous and homogeneous) and the construction site (which is instead heterogeneous and cyclical). Lastly, IBS requires skilled and trained labour (Jiang et al. 2018; Chao et al. 2015) and can hardly be entrusted to general-purpose subcontracts, requiring significant investments in training for personnel.

The **designer** generally does not accept IBS as he fears they may limit his creativity (Boafo et al. 2016) and the early freeze design (Elnaas 2014) does not allow him to carry out design actions in parallel with the implementation phases of the project, thus requiring considerable investments of time in an accurate design, for which the professional studios are not equipped and for which the extra design costs would not be recognized.

Another aspect that hinders the spread of IBS can be found in the scarce **institutional sustainability**, i.e. the lack of characterization of the standard to allow and support innovation: off-site industrialization sometimes struggles to find adequate acceptance by local authorities (Elnaas 2014) and a precise location within standards designed for traditional on-site construction (Jiang et al. 2018). Furthermore, the aspects of "plus enhancement" are often not recognized, as in the case of CAM or Uni PdR13 (Ginelli et al. 2019).

27.3 Acceptance and Sharing of Innovation Processes

Some non-acceptability factors have a conjuncture and structural nature, linked to the Country-system and to the structure of the economy itself. Only targeted policies and long-term investments, especially public ones, can influence these factors.

[5] i.e. construction companies.

However, there are non-acceptability factors, related to an erroneous and fearful vision of innovation, which can be overcome through an adequate transmission of information, team planning and the dissemination of virtuous and paradigmatic examples of achievements. Furthermore, in the transformation of the market, innovative approaches to living are bringing out (Fig. 27.1), which are stimulating the interest also of sectors previously unrelated to innovation for which the trinomial project/process/production is emerging as a new correspondence and the anticipation of decisions is becoming a cornerstone of the design approach.

These new approaches outline a design "process" that is increasingly in a "platform" of processes and actors, understood as a virtual place of meetings and connections able to generate the project. Below, an example concerning a product innovation linked above all to process innovation that has been able to share objectives and examples of innovative management that, starting from market changes, is a potential supply to seize the opportunities offered also by technical innovations.

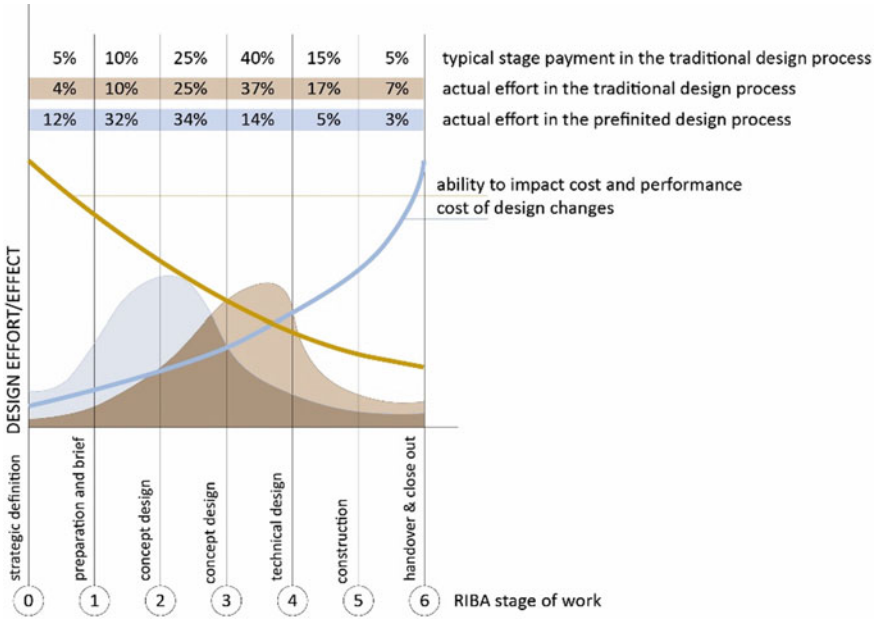


Fig. 27.1 Elaboration of Macleamy curve with data (UK market) Avalon Building, from www.avalonbuild.co.uk (visited on March 2022) that shows sharply the transition from a traditional process (brown) to an innovative one (light blue)

Table 27.2 Satisfied requirements of cHOMgenius project

Requirement (UE 305/2011)	Responding features
Mechanical resistance and stability	Project of specific seismic isolator, auto-centring and easy-replaceable, tested on seismic and safety simulator
Safety in case of fire	Structure, partitions and insulation are completely non-flammable
Hygiene, health and the environment	Internal surfaces are easily cleanable and waterproof
Safety and accessibility in use	Electrical plants are low voltage (24 V), and all plants are flexible and adaptable
Protection against noise	Reverb is excellent thanks to corrugate sheet and specific acoustic panels. Facade insulation is compliant with legislative prescriptions
Energy economy and heat retention	Off-grid management of energy guarantees zero energy consumption, also allowed by high specific heat of the envelop (more than 20 h of shift)
Sustainable use of natural resources	The use of reuse container as structural system brings incorporated energy of structure to 0 and the 30% of reduction of total CO_2. All the components are easy disassembling and reusable or, at least, recyclable

27.3.1 An Affective Example of Product Innovation and Sharing Project in Italy

The project "cHOMgenius. PrototypeSystem&SharedProject. Extraordinary solutions for smart living",[6] partially funded by Regione Lombardia Smart Living, is a two floors permanent residential building, entirely dry-joint with clamping techniques, built off-site using HC shipping container, off-grid and entirely dismantling and reversible. The very high satisfied requirements (Table 27.2) achieved are the result of the sharing of objectives, right from the first design phases, of 22 companies, in addition to the scientific support of the DABC of the Politecnico di Milano and UNI.

Product innovation lies above all in the transfer of techniques and products from the mechanical industry and in the development of nodes that, thanks to the continuous and effective interaction of all the actors involved, have allowed significant improvements in performance and reduced production times, as in the case of the interface between window and opaque casing described in Fig. 27.2.

Thanks to the effective application of the decision anticipation principle, based on an open, collaborative and cooperative design method, cHOMgenius has developed techno-typological solutions that demonstrate (Fig. 27.3) the great flexibility of the aggregative variants and the complete customization of spatial configuration, functional and finishing solutions (Pozzi 2021).

[6] https://www.dabc.polimi.it/en/ricerca/ricerca-competitiva/chomgenius-prototypesystemshared project/.

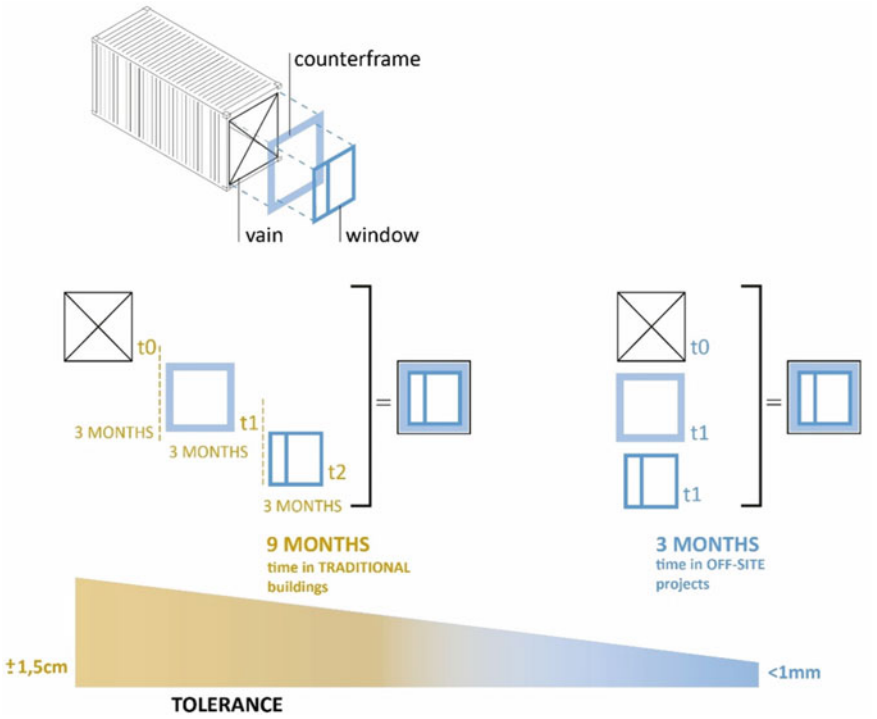


Fig. 27.2 IBS and tolerance: small off-site tolerance (< 1 mm) allows saving time in many operations. The example above is the interface between wall and window: in a traditional process (left with ± 1.5 cm tolerance) after the realization of the vain in the wall, you have to measure it and start making the counterframe. After the counterframe positioning, you have to measure it and start making the window (9 months in total). If you work with mechanical off-site precision all these operations can be made in parallel reducing by one-third the time

Fig. 27.3 Images of cHOMgenius project prototype in Busnago MB (from the top left, clockwise): transportation of the first module, factory assembly of the structure of the "other space", external south view, internal view from the mezzanine, internal view of the double-floor residential space and internal view from the second floor. All images by the authors

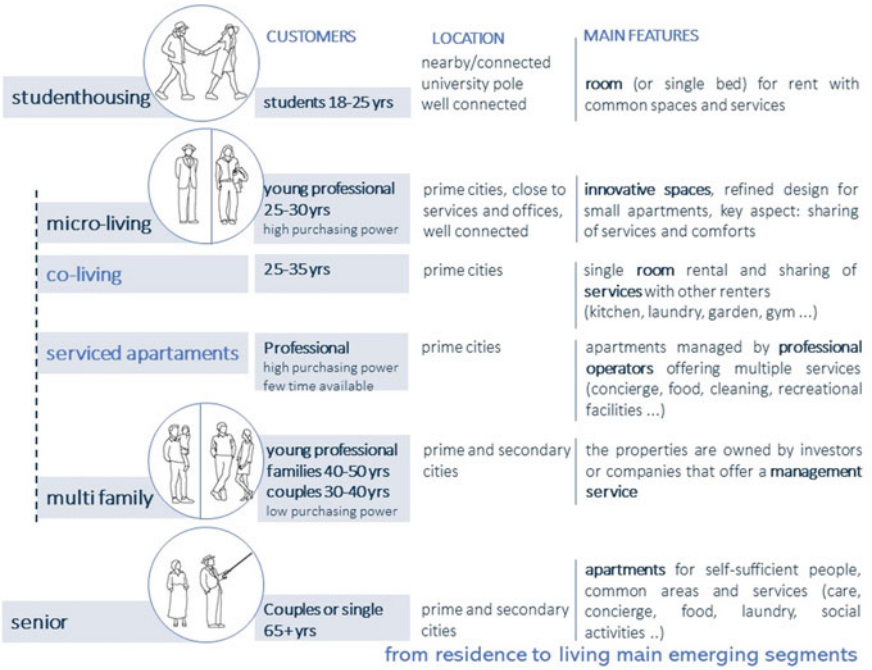


Fig. 27.4 Reorganization of the real estate market for new housing demands. Elaboration from ANCE (2019)

The residential market has partially diversified the demand for living spaces, especially in four emerging segments (ANCE 2019): student housing, micro-living, multifamily and senior housing (Fig. 27.4), where flexible, dynamic common spaces and services are crucial.[7] In Europe, living reached 83.4 billion in investments in 2020 (+10% in 2019) and diversification is a new investment strategy (Aberdeen Standard Investments): from a survey on 40 investors, 63% intend to expand into multifamily, 34% in student housing, 10% in co-living.[8]

From the management point of view, these models introduce hybrid housing typologies between domestic environment and services, to satisfy transitory needs for a short fixed time, where high performances are required at low management

[7] According to Savills' report "Global Living Report 2020" real estate investments in the residential sector worldwide accounted for 27% of global real estate investments, (+11% compared to ten years ago), in particular with the following investments:

- Multifamily: $223 billion transacted globally in 2019.
- Senior Living: $21.4 billion in investments in 2019.
- Student housing: three most active investors Blackstone iQ Student Accommodation for 6 billion dollars.

[8] Investimenti immobiliari, tutti pazzi per il "living" (mark-up.it).

Fig. 27.5 Main aspects underlying the "Industrial rental market". Elaboration from ANCE (2019)

costs, in a "package" that provides for furniture, energy supply contracts, maintenance, management (Glumac and Islam 2020). An example is the city-pop[9] model, developing in Milan and other European cities: micro-apartments and common areas (co-working, restaurant, minimarket) with optional services that can be managed via application (laundry, cleaning, booking, consumption, service management). A further example is the Ambient Assisted Living technologies in senior housing,[10] to manage the environment and monitor vital activities. The future of the housing market will also deal with the new structural ways of working remotely: for tertiary buildings, there will be a resizing of spaces, accompanied by an important divestment, and for workers, there will be the possibility of opting for locations far from companies and the need for adequate living spaces to support smart working.

27.4 The Missing Ring: The Innovative Management of Industrialized Buildings as an Open Conclusion

Some Contemporary "green" demands require high-performance and reversible buildings, low management costs, high maintainability and durability. In parallel, the housing market is orienting towards less stationary forms of housing that favour a temporary short-term lease (Fig. 27.5).

The conclusion of this contribution is, after having underlined and connected these two instances, that they must find a point of contact and converge for mutual benefit. It is in fact essential for a manager of estate asset, with dynamic management of the users, to rely on properties able to absorb new models of life and make the

[9] www.citypop.com.

[10] As examples www.seniorhousingitalia.it or www.amatilive.com.

management sustainable, especially from an economic point of view. Specifically in Italy (but not only), the obstacles to industrialization are often linked to the idea of a home as a durable (almost eternal) resource and to a stationary form of living that has made the house an experience of belonging. The lease, with a strong vocation of reduced temporariness, undermines these constraints and gives to builders an "industrial" way of building as "industrial" is the rent required today (ANCE 2019).

This convergence allows the client more awareness to find the most suitable systems that guarantee a flexibility and functional transformation and quality over time that allow an adequate management of the assets (Ginelli and Perriccioli 2019). It allows the world of production to interface with informed clients who need building stocks to be managed (and therefore to be realized) with adequate systems suitable for the scale of the intervention, thus initiating economies of scale that requires the use of IBS. Finally, the scale of the intervention allows designers to invest time in the design of reversible functional spaces, which can foresee the changing needs of users and which allows them to prototype and test, before the construction site, the appropriate technical solutions.

Thanks to cHOMgenius project, we have demonstrated that an effective IBS for housing is possible in Italy too and the highlighted new tendencies of the market confirm the changing of a paradigm for housing. The future research and experimentation we call for are related to the institutional dimension of sustainability: in order for these new processes and these new production systems to generate effective and incisive operating models and constructive syntax, and it is however essential that the legislator creates the appropriate conditions, providing clear indications on the choice of innovative construction systems, instead of, as also outlined by the PNRR, generically financing the sector, thus leaving room for those same lobbies that have hindered a real transformation of the construction market in past cycles.

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