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2024
(7th) Residential Building Design & Construction Conference Proceedings

May 27-28, 2024

Edited by
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PennState College of Engineering | PENNSYLVANIA HOUSING RESEARCH CENTER

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Preface

The home building industry is trying to accommodate much talked about design and construction criteria, such as affordability, energy efficiency, sustainability, serviceability, aesthetics, utility, a low carbon footprint, and hazard resistance, among others. Accordingly, there is a great need for technology transfer from building material and product manufacturers, as well as designers and standard/code developers, to designers and home builders. The Pennsylvania Housing Research Center (PHRC) at The Pennsylvania State University is pleased to offer knowledge sharing and dissemination of the results of recent advancements in the residential construction field. The PHRC proudly continues to organize the Residential Building Design and Construction Conference series in order to support knowledge and technology transfer to the housing and residential construction industry.

We are pleased to share the proceedings of the 2024 Residential Building Design and Construction Conference, which was held on May 27-28, 2024. As in the past six RBDC Conferences, the 7th conference brought together researchers, design professionals, manufacturers, builders, and code officials to have a dialogue on the latest advancements in research and practice and to share their contributions in this field.

The 2024 RBDC Conference hosted 89 attendees and included 59 papers, 54 presentations, and 6 posters on various issues related to residential buildings, which encompass single- and multi-family dwellings, mid-rise and high-rise structures, factory-built housing, dormitories, and hotels/motels. Papers and presentations related to the following areas and topics were invited in the conference call:

- 3D Printing
- Aging in Place
- Building Design & Climate
- Building Envelope - Airtightness
- Building Envelope - Building Science
- Building Envelope and Energy Efficiency
- Building Materials, including Hempcrete
- Disaster Resiliency and Mitigation
- Healthy Homes
- High-performance Housing
- Housing Policy and Affordability
- Housing and Society
- Mechanical Electrical & Plumbing (MEP)
- Residential Construction Education
- Structural Design & Wind Loading

As the list of presentations in the program schedule and the list of papers in the Table of Contents of these proceedings show, the above broad topics cover most of these contributions at the conference. The presentations clearly show contributions related to the following topics: building envelop, building science, air tightness, energy efficiency, building materials, disaster resiliency, healthy and high-performance homes, affordability, MEP, wind loading and residential construction education.

Two keynote speakers were invited for the conference: Vivian Loftness, Paul Mellon Chair in Carnegie Mellon University's School of Architecture, and Graham Finch, Senior Building Science Specialist with RDH Building Science, Inc. Loftness discussed her presentation entitled "Environmental Surfing at Home for a Resilient Future." Finch shared his presentation entitled "Lessons in the Development of Innovative Prefabricated Façades for Mass Timber Buildings."

We wish to thank the members of the International Scientific Committee of the conference for their contributions in promoting the conference. The support of the PHRC staff for logistics is also gratefully acknowledged.

Proceedings Editors:

Ali M. Memari
and Mindy Boffemmyer

May 2024

Wednesday, March 27 Schedule

8:15 AM Opening Remarks: Dr Ali Memari

8:30 AM Keynote: Vivian Loftness, "Environmental Surfing at Home for a Resilient Future," Room 207

10:00 AM Break with Exhibitor Plus Sponsors and Snacks, Break Area

10:30 AM

Building Envelope | Building Science
Room 204

Moisture Control with Continuous Insulation
Justin Koscher and Marcin Pazera

Hello Ci, Meet Windows and Siding. Now Get Along!
Jay Crandell

In-Situ Field Study and WUFI Simulation of the Hygrothermal Performance of a Cross-Laminated Timber/Wood Fiber Insulation Building Assembly
Liam O'Brien, Jake Snow, Ling Li and Benjamin Herzog

Aging in Place
Room 203

A Net-Zero Energy Aging-in-Place Solar-Powered House Design
Hessam Taherian, Rahman Azari and Lisa Iulo

How Did the COVID-19 Pandemic Affect the Shared

Living Model for Aging in Place: Case Studies in British Cohousing Communities
Jingjing Wang

MEP
Room 202

Ductless Heat Pump Energy Monitoring in a Cold Climate
Vanessa Stevens, Rachel Dodd, Andrew Worthman, Tom Marsik and Jessica Biddle

Lessons Learned from Demand Control Ventilation in Commercial Buildings and Their Application to High-performance Residential Buildings
Niloufar Ghazanfari and Georg Reichard

Evaluation of Artificial Neural Network and Multiple Linear Regression Models for Indoor RH Prediction of a Residential Building in a Marine Climate
Yina Shang and Fitsum Tariku

Housing & Society
Room 218

Challenges in Mixed Methods Research: Data Collection and Assessment of IAQ in Low-Income Households
Ramyar Tajik and Simi Hoque

A "Connected Communties" Approach to Delivering Value to Builders, Property Owners, Utilities, and Customers
Ari Rapport

12:00 PM Lunch, The Gardens

1:00 PM

Building Envelope | Airtightness
Room 204

Study on Airtightness of Partition Walls between Adjacent Residential Units
Michal Bartko, Travis Moore, Heather Knudsen and Iain Macdonald

Commercial Whole Building Airtightness Testing ....Don't Be Scared!
Adam Ugliuzza

Methods for Detection and Quantification of Building Leaks Using Background-Oriented Schlieren Imaging
Gurneesh Jatana, Philip Boudreaux and William Partridge

Healthy Homes
Room 203

Impact of Light Level on Physical Self-Maintenance of Elderly Dementia Patients in Care and Attention Homes
Mei-Yung Leung and Yueran Li

A Review of Relationships Between Residential Environments and Human Health
Tasneem Tariq, Sina Memarian, Lisa Domenica Iulo and Rahman Azari

Understanding How Different Building Designations Impact Conscious and Unconscious Evaluations of Housing Developments
Isabella Douglas and Sarah Billington

Residential Construction Education
Room 202

Online Programs in Residential Buildings Energy-Efficiency: Curriculum Design, Development, and Delivery
Omar Al-Hassawi

Reimagining How We Live:
The HUD Innovation in Affordable Housing Competition
Joe Colistra and Nilou Vakilbahrami

2:30 PM Break with Exhibitor Plus Sponsors and Snacks, Break Area

3:00 PM

Building Envelope | Building Science
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Philip Boudreaux, Stephen Killough and Diana Hun

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Daniel Hindman and Joseph Loferski

Building Design & Climate
Room 203

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Silvia Brunoro, Giacomo Bizzarri, Laura Ferrari and Enrica Boldrin

Integrated Design for Environmental and Climate Justice Research, House 360
Jessica April Ward

Residential Construction Education
Room 202

Alley House: Educational Highlights from Ball State University's 2023 Solar Decathlon Build Challenge Project
Tom Collins

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5:00 PM Networking on the Exhibit Floor, Deans Hall

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8:30 AM Keynote: Graham Finch, "Lessons in the Development of Innovative Prefabricated Façades for Mass Timber Buildings," Room 207

10:00 AM Break with Exhibitor Plus Sponsors and Snacks, Break Area

10:30 AM

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Jonathan Bluey, Philip Agee and Andrew McCoy

A Comparison of Single Family Home Energy Usage Based on Exterior Wall Assemblies and Insulation
Ben F. Bigelow, Somik Ghosh and Francesco Cianfarani

Guidance for the Evaluation and Early-stage Design of Mass Timber and Hybrid Mass Timber Floor Syste
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Gerald Steyn

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Understanding How Different Building Designations Impact Conscious and Unconscious Evaluations of Housing Developments
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Edward Louie

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BUILDING MATERIALS

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MECHANICAL, ELECTRICAL & PLUMBING (MEP)

RESIDENTIAL CONSTRUCTION EDUCATION

STRUCTURAL DESIGN & WIND LOADING

New Living, New Housing, New Systems for the Built Environment

E. Ginelli[1], L. Daglio[2], G. Pozzi[3] and G. Vignati[4]

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ABSTRACT

The state of housing in Europe is rapidly evolving, as living needs are changing due to demographic fluctuations and work and family dynamics. Real estate market investments have been diversifying the housing offer, mainly towards short-term, flexible (spatial, functional, lease contracts) for rental accommodations. Among these new perspectives, the “house as a service” model, which incorporates both specific housing and residences or hotels features, is emerging. Starting from the socio-demographic dynamics and rapidly changing market trends, this contribution argues that, in order to renew current housing models, design should include technical-constructive and functional-standardizing aspects to foresee possible spatial and functional transformations over time, in order to satisfy the multiple needs of users and stakeholders. The research deals with the evolution of living spaces in Europe and the added value stemming from industrialized processes and dry assembly technologies, in terms of social, environmental, economic, and operational benefits. The research explores modularity as a design tool, complying with the multiple regulatory requirements of different programs, to pursue flexible and transformable housing solutions. Case studies, design tools, and operational models for the regeneration of the built environment are disclosed to overcome the concept of irreversibility, in order to achieve a “continuous functional convertibility.” By applying the principle of “anticipating decisions” and the design tool of “modular dimensional coordination” (where the module is not only spatial, but an ordering and regulating tool), the result outlines design guidelines capable of connecting new living needs with new technological solutions, in a condition of economic and institutional sustainability.

EVOLUTION AND NEW TRENDS IN CONTEMPORARY LIVING PATTERNS

Due to the evolving nature of living spaces in Europe, the USA, and Asia over recent years, shifts in work and demographic factors have altered lifestyles. This has resulted in urbanization, an increase in housing demand, and greater mobility within metropolitan areas. (Smith, 2021). In this scenario, within the private sector, the role of short-period rent (with a duration of 6 months)[12] has been progressively (Hoolachan, McKee, Moore and Soaita, 2017) boosting the demand for temporary housing in a real estate market marked by a reduction in economic solvency (Deloitte Real Estate Predictions, 2021). Accordingly, the following emerging features of residential spaces can be highlighted.

First, the evolution of the living market has fostered the house-as-a-service concept understood as a ready-to-use house (Hoang and Vandal, 2017) that includes living spaces fully furnished and with a series of extra services, to be rented for short periods. The house-as-a-service for the inhabitant is designed to satisfy a temporary need and not as a permanent housing solution. This concept of living is addressed to diversified categories of users, such as students, city users, fixed-term workers--people who transition through metropolitan areas for various reasons (IZA Institute of Labor Economy, 2019). These housing demands share common conditions involving the availability of resources (especially economic resources of the users, in urban areas where costs are increasingly higher) through a downsizing of the living space (Clinton, 2018), with the presence of accommodation spaces, common areas, and location of services (inside the building or remotely on-demand). In terms of design/construction/management solutions, these characteristics belong to different housing models, such as co-living, micro-living, student housing, and senior living. Despite the diversity of users, these models have the following common characteristics:

- they are often managed through agencies or organized through peer-to-peer platforms. This management concerns the rent, the use of shared spaces, and services, such as cleaning (Harris and Nowicki, 2020).

- they have shared spaces, such as kitchens, co-working for self-employed and freelance workers, gyms, laundry, gardens/terraces, and entertainment areas (JLL Reports, 2018).

- they are fully furnished, to make the living space functional and transformable during the day. In the design, there is an integration with the equipment, such as the use of functional blocks, or through solutions that exploit the height of the room with mezzanines or with mobile elements (Gronostajska, Szczegielniak, 2021; Daglio, Ginelli, Vignati, 2023).

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[12] https://www.tribecoliving.com/

- they are "ready to use," often containing all the furniture and accessories of a residence or hotel; they are in well-served areas; the common services are attractive and calibrated concerning users (JLL Reports, 2018).

The rents of these housing models are often very expensive (Harris and Nowicki, 2020), (especially for co-living and micro-living), compared to other private rents in similar areas. For example, the living space at The Collective[13] in London involves £1,083-1,300 per month; in the same locality, the cost of a room in shared accommodation is between £500-750 per month, while the rent of a studio flat is around £800[14]. Similarly, Node Living in Bushwick, New York, charges US $2,775 a month[15], compared to about US $1,800 a month in the same area for a one-bedroom apartment[16].

These new forms of living have accentuated the transition from house "as a good" to "house as a service" that, drawing inspiration from the service-oriented models seen in other industries (such as transportation or hospitality), entails solutions as a flexible and on-demand service, instead of traditional property ownership or long-term rentals. In fact, as described by Wallman (2017) "one of the reasons why we are less concerned about owning things is that now we can have all the advantages of access to a good, without the hassle of owning it."

THE DESIGN CHALLENGE

The intersection of evolving living standards and market offerings should prompt a practical and factual reconsideration of construction methods. Rather than being solely the choice of construction companies, innovative systems should be integrated from design to construction techniques. Furthermore, design should include technical-constructive and standardising-functional aspects to foresee possible spatial and functional transformations over time, in order to satisfy the multiple needs of users and stakeholders. Hence, the project should also prioritize the central concept of flexibility. This encompasses not only contractual aspects but also spatial and managerial considerations, involving both the construction dimension and the entire design process. Buildings should be understood as potentially multifunctional organisms capable of varying over time (ANA, 2014), in order to respond to the need for future changes and to empower user influence in architecture (Kompier, 2014). From this assumption, in addition to pursuing contemporary needs, design is able to anticipate the continuous flow of innovation (Sposito and Scalisi, 2023) and, therefore, is able to build a new ecosystem, capable of fully integrating into the circular economy.

Architects have seen the potential of the anticipatory role of design by studying solutions for the transformability of living spaces, proposing spatial-distributive,

[13] https://www.thecollective.com/about-us.

[14] https://www.rightmove.co.uk/

[15] http://node-living.com/

[16] https://www.zillow.com/bushwick-brooklyn-new-yorkny/apartments/

techno-typological, and constructive flexibility in order to make spaces more responsive to the changing needs of its inhabitants. This research targeted buildings with a predefined program: housing, offices, etc. (Perriccioli and Ginelli, 2018). However, today buildings cannot fail to be reactive, "eco-responsible"[17], and modifiable at low costs, enriching the design dimension through the functional mix, reversibility and convertibility (Ginelli, 2021).

Reflecting on the relationship between construction and circular economy, Patrick Rubin (2017) indicates, together with other construction parameters[18], the maximum percentage of future transformation as a fundamental parameter for optimizing costs, both for new building interventions, and in redevelopment--provided that the initial potential flexibility is assessed, and the consequent degree of flexibility is planned. However, achieving such an enriched concept of flexibility, facilitating seamless transitions between different building programs, necessitates the anticipation and fulfillment of various future user and stakeholder needs over time, while simultaneously complying with diverse building regulations. Therefore, a meta-design approach becomes essential to anticipate sets of potential future conversions and to define a schematic layout capable of accommodating these anticipated transformations. This paper delves into the potential of modularity as a design tool to guide the formulation of such a layout, enabling adaptation to a range of planned programs and addressing multiple legislative spatial and indoor comfort constraints. Contemporary case studies and current design approaches are introduced to contextualize the concept of modularity, which is presented as deeply rooted in literature and explored for its potential as a control device in providing a foundational pattern, a multidimensional regulator for design closely linked with construction techniques. Finally, the concept is tested in a renovation project to uncover limitations and suggest possible avenues for further research and development.

DESIGN TO ACCOMMODATE CHANGE

Current international research on living and its relationship with the time variable, declines the concept of flexibility in terms of adaptability and reversibility, encouraging the functional mix and laying the foundations for that "openness to change" mentioned above. The "Open building"[19] design approach and the CIB W104[20] working group have been studying methods to create buildings adaptable to changing housing needs, in order to reduce the waste of materials and support the need for change of the building's users. The concept is based on the breakdown of the building system into different levels ("layers" Brand 1994) and the separation of two components ("supports" and "infill"), having different longevities and that are physically separated, to facilitate their replacement and allow the adaptability to user

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[17] Recalling the term used by Jourda (2009), maintaining that the architect does not design only for a client or a user, but for everyone with environmental, social and economic consequences.

[18] Depth of the building, internal height, added external elements, distribution, construction methods, structure.

[19] https://www.openbuilding.co/manifesto

[20] http://open-building.org/about/objectives.html

preferences over time (Kendall and Teicher, 2000; Kendall, 2021). This layer separation is based on industrialized construction and pre-assembly, with appropriate reflections on the interface nodes.

An example of application of the Open Building principles is the Solis IJburg project (Figure 1), in which buildings can satisfy the need for adaptability from an office function to a residential one, through an arrangement of the rooms inside of an open plan. The supporting structure is in reinforced concrete, with the positioning of the stairwells in compact cores. The internal heights (3.40 m) and the internal walls (non-structural) allow flexible uses; the units (max depth 20.00 m) can be used as offices, studios, hotels, studio flats, and apartments.

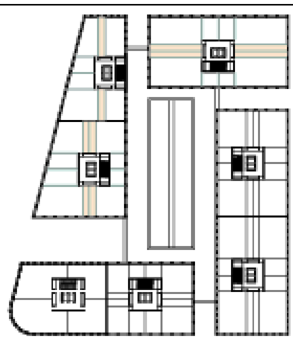
	project data	Solids IJburg, 467, Amsterdam, 2011
	promoter	Stadtgenoot Amsterdam
	designer	Baumschlager Eberle
	manager	-
	1st configuration	mixed-use, currently offices
	2nd configuration	potential future conversion in offices, hotel rooms, care spaces, apartments, studios
	building typology	court
	source	https://www.baumschlager-eberle.com/werk/projekte/projekt/solids-ijburg-amsterdam/ http://www.open-building.org/conference2011/Project_Solids.pdf

Figure 1. Solids IJburg, Baumschlager Eberle (2011), Elaboration by Vignati, G.

Resuming the theory of "layers" and the organization of interfaces between components, the "Adaptable Futures" research centre in Loughborough[21] reflects on the relationship between adaptability and sustainability and the positive impacts that the transformative capacity of a building has on extending its useful life (postponing its demolition or abandonment).

The time factor indicates that buildings are dynamic systems, interacting with an evolving set of needs. "Adaptability can be seen as a means to decrease the amount of new construction (reduce), (re)activate the underutilized building stock or vacuum (reuse) and improve disassembly/dismantling of components (reuse, recycling) -- extend the useful life of buildings (reduce, reuse, recycle)" (Schmidt III, 2016). The

[21] http://adaptablefutures.com/

concept of adaptability is linked to three main aspects: i) the specificity of the building; ii) strategic focus (i.e. based on the identification of specific areas in the building that allow adaptability), and iii) the object with adaptability. This point of view is closely linked to personalization by the user, taking up the concept of flexibility expressed by Schneider and Till (2007).

A third relevant example is the French approach to the topic "Architecture reversible" (Rubin, 2017), which underlines the need to encourage innovative regulating tools, highlighting the role of the design process, in order to give the building the ability to change over time, and emphasizing interest in proposing building interventions capable of responding to changing needs over time. This ability is declined in the term of *réversible*, defined as the programmed ability of a structure to modify its functional destination, through a design that minimizes adaptations (Rubin, 2017) and provides for the transition from a first functional destination (such as the office), to a second one (such as the residence). The term *flexibility* is associated with the possibility of configuring an internal space, thus limiting it to customization (of finishes or sizes of the housing units).

In this scenario, the construction of a reversible building (Logements réversibles) in Bordeaux is underway, by Patrick Ruben (director of the Canal Architecture studio)[22]. The assignment of the project, through a call for applications (announced by three public entities: Bordeaux Euratlantique, Euroméditerrannée, and Grand Paris Aménagement in 2018), was won by the Canal Studio through the proposal of a reversible building, as part of a "permit to build without prior assignment" of destination (Figure 2).

[22] https://canal-architecture.com/

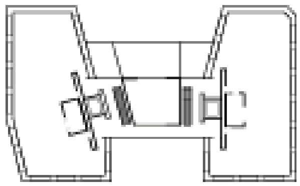
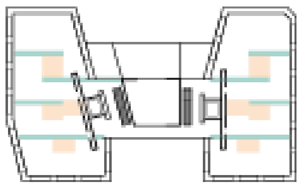
	project data	TEBiO Logements Réversibles Euratlantique, Bordeaux, 2024
	promoter	Bordeaux-Euratlantique, Egidia/Elithis et Catella
	designer	Canal architecture
	manager	Bordeaux-Euratlantique
	1st configuration	residence, offices nursery (ground floor non-reversible)
	2nd configuration	potential future conversion of space and function (first “reversible building” building permit issued by the French state)
	building typology	court
	source	https://www.franceinter.fr/emissions/l-urbanisme-demain/l-urbanisme-demain-du-samedi-08-janvier-2022

Fig 2. EPA Bordeaux-Euratlantique Canal architecture (2022), Elaboration by Vignati, G.

The Module as a design regulator

Alongside flexibility, “modularity is the tool for a conscious design order” (Nesi, 1977). It includes the provision of a measurement module for dimensional coordination and a material module for constructive coordination. Dimensional and functional coordination constitutes the practical link between design, the production of components, assembly, quality, and cost control. Unlike Anglo-Saxon research, the term “modular” adopted by the authors in this contribution, has an additional value, indicating a “regulating role” and rhythmic aspect. Therefore, it does not refer directly to the concept of a “pre-assembled cell” that much international scientific literature associates with the term “modular”[23]. This contribution adopts this meaning to deal with the modularity for living today: the module is understood as a unit of

[23] We recall some international definitions used in relation to the term "modular", associated with the concepts of off-site construction and prefabrication:

“Modular Architecture presents mass-customized mid- and high-rise modular housing that can be manufactured and distributed on a global scale” (Wallance, 2021);).

“Modular construction refers to 3D units that are fully fabricated in the factory and are assembled onsite to create complete buildings or parts of a building” (Jammi, Sanjeevi, 2021); “Modular).

“Modula construction has the potential to improve housing cost, combining designing modular housing with an off-site construction” (Bayliss and Bergin, 2020);).

“Modular construction involves producing standardized components of a structure in an off-site factory, then assembling them on-site” (McKinsey and Company, 2019);).

“Modular Construction is the process in which a building is constructed off-site, under controlled conditions, (...). The process consists of buildings produced in modules to be later put together on site” (Real Projectives, 2019).

“Modular Construction: a prefabricated construction technology using volumetric units” (Lawson et al., 2014).

measurement[24], proportion, structure, ability to manage a relationship between parts, and therefore, the human ability to perceive, simplify, represent the environment and, consequently, to structure it (Meltzer and von Oppeln, 2016). This approach to modularity also acts as a strong incentive to functionality, promoting the production and spatial management for a sustainable circular economy, maximizing the reuse of the building. In fact, the parts of the modular system, if appropriately designed, can be easily replicable, scalable, and interchangeable, allowing various levels of flexibility and customization. In the history of architecture, depending on the relationship it had with building, the module has been used as module-object and module-measurement, compositional module, constructive module, and typological module. Recalling Argan (1965), the module-object represents “an ideational principle” which is at the same time “the basic fact of the construction.” Unlike the compositional and measurement module (abstract dimensional entity useful for establishing quantitative or qualitative metric relationships between the parts of a building), the object-module is defined as a physical entity and coincides with an element produced industrially according to prefabrication methods (Campioli, 2003).

The concept of the module can be also understood as a regulating unit of space and as a physical element (the constructive module), whose proportions determine the final result of the assembly, used as a tool to support industrial production. An application example is the experience of Wachsmann (1961) in identifying a basic module universally shared by industrialized production.

This dimensional and modular coordination is based on a system whose reference is made up of a triad of orthogonal Cartesian axes (x, y, z) and whose unit of measurement for attributing the theoretical dimensions of coordination is made up of the module. The reference design modular grid (horizontal or vertical) can be alternated (forming so-called “tartan” grids, from the tartan fabric, Figure 3) or interrupted by bands of modular thickness (Maggi and Morra,1979; Novi, 2010).

Figure 3. Example of dimensional and modular coordination, Elaboration by Vignati, G., based on an unpublished work by Ceriani, J., Frontera, E., Faldrini, F.

[24] From the Latin *modŭlus*, that which serves as a measure, assumed as a reference unit.

An example of experimentation

The following case is an experiment conducted by the authors[25] involving the "regeneration" over time of a decommissioned tertiary building, built in the 1980s and located in Milan, Italy. The study involves the functional reconversion of temporary living spaces, intended for different categories of users, to identify technological and constructive solutions capable of supporting the functional transformability of the spaces. The adopted methodology incorporates modularity and techno-typological flexibility to allow functional convertibility (Pinder et al., 2017), i.e. to allow rapid change in the functional destination of the environments over time, encouraging the multifunctional character of the intervention. The modification of the various conditions of use is implemented through localized interventions in predefined areas, in particular through the insertion of easily removable prefabricated dry walls, and the identification of certain areas corresponding to the bands of the modular grid. Figure 4 illustrates the identification of the modular grid (tartan) and the possibility of hosting different temporary housing forms, conceived as house as a service, from the hotel to the student residence, to the senior residence.

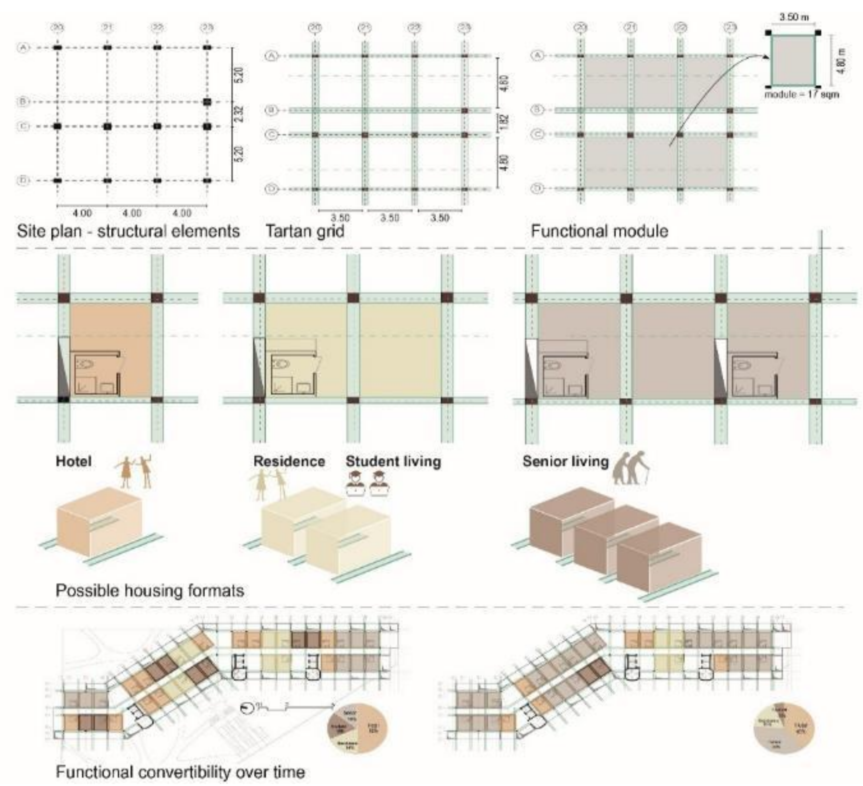


Figure 4. Example of technical-typological solutions for transformability, Elaboration by Vignati, G., based on an unpublished work of Ceriani, J., Frontera, E., Faldrini, F.

[25] Within a research agreement between a real estate operator and the ABC Dept. of the Politecnico di Milano, coordinated by E. Ginelli.

In applying the evolutionary principle, experimentation introduces a spatial, dimensional, and regulating modularity to ensure functional coordination. This modularity identifies a dimensional module in accordance with specific legislative requirements, allowing different but compatible functions to coexist and overlap. It satisfies changing needs and qualitative-quantitative requirements envisioned by the rules for the coexisting functions over time (Ginelli, 2020 p.47).

CONCLUSION

In recent years, we have witnessed a rapid and incremental evolution of lifestyles and corresponding ways of living. Numerous research efforts and experiments have been undertaken to address these changes and anticipate their future trajectory. The research and experiments presented here propose an initial path to be further explored. This involves broadening the scope of case studies to be tested and deepening our understanding of the economic and social feasibility throughout the entire project life cycle, including the process of consecutive transformations. In addition, there is a need to investigate the reasons preventing the possible market acceptance of these systems in order to overcome them. However, as the changing needs of the market require technical innovation, even more a cultural change should occur to be supported by institutional innovation. On the one hand, design methodologies require a paradigm shift so that the building can conquer “new lives;” on the other hand, its feasibility relies on a revision of the legislative and procedural apparatus to support, incentivize, control, and certify design experimentation, which results could, in turn, stimulate regulatory innovation. The current approach of planning rules, apart from a few selected exceptions,[26] does not allow an easy change’ between different building programs, de facto stifling innovation and changes aimed at satisfying the evolution of the housing demand’ and the achievement of sustainable goals through a reduction in the construction works environmental impact.

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[26] Milan's PGT 2030 (planning regulation) proposes "functional indifference" to prevent buildings abandonment and promote a functional mix. Tools like "Permis d'Innover" and "Permis expérimenter", recently tested in France, offer reversible authorization for office buildings, reflecting far-sighted support for renewal. These initiatives anticipate challenges that architects and the construction sector will face in the years ahead.

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