

## Original Paper

# Inhabit the Change: Circular Design & Iot

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### Abstract

*To solve the problems associated with precarious contemporary housing, it is essential to intervene with structural housing reform. Therefore, it is necessary to start from semantics and read space on the one hand, as a **moment** where history, traditions and culture meet; on the other hand, as a key to overcome obstacles and general obsolescence.*

*The state of the art includes: repetition of self-built and unregulated low-quality typologies, high migration rate, and socio-economic changes; the consequences are: low-quality buildings, overcrowded or uninhabited urban centers, obsolete spatiality. Today, the challenge is to design in a short time and with high qualitative standards, without giving in to hypertechnology but finding a balancing strategy. It is a matter of anticipating what cannot be expected, and responding to the multitude of ever-changing needs inherent to an atypical user.*

*“Inhabiting” in this perspective must be increasingly “smart and sustainable”. This is done through interactive design, which increasingly uses digitized services and connects objects and people. The goal is to move towards DfD, «Design for Disassembly», through “**change**” as a paradigm, and the solution is in our homes.*

### Keywords

*circular design, recycled materials, smart building, safety dwelling, IoT, design for disassembly*

## 1. Introduction

If we go through the historical evolution of *inhabited anthropic spaces*, we can see that the house (as a “safe place”) and its outside, had to adapt to many changes. These changes do not only concern the design process or the technologies, but better the relationship between *home* and *households*. In fact, although these aspects are getting closer to high performance standards and are able to reduce the carbon footprint, according to Paul-Henry Chombart da Lawe the human-space link is so strong that we can speak of a *coincidence between spatial unit and social unit* (Ceci, 1996).

The diversity of patterns and family types in which the contemporary enters, exceeds the functionalist vision of the house as a “machine à habiter” (Le Corbusier, 1923); we need to rethink new paradigms that both consider the different ways of *dwelling* and are based on an anthropocentric dimension of the residential building.

*The house is today one of the universal places where we can rethink ourselves and the inhabited world: it has become a real laboratory of understanding and transformation of the world (...), it is the place where our public dimension has been reworked and filtered through a personal time and through small operations that define a useful distance. Today, this dimension seems to become thinner under the pressure of “digital time”, that imposes and reduces the moments of seclusion and silence* (Molinari, 2017).

The dwelling space became fluid, without boundaries and thresholds, and the need to have virtual limits arises, however, virtual space, like the real one, «is not something that stands in front of man (...), the relationship between man and space is nothing other than the *dwelling* into its being» (Heidegger, 1976). In other words, space exists at the same time that we inhabit it.

## 2. Method

All the inputs that revolve around home design itself, must be organized into actions: *evaluation and deconstruction, investigation, connection*. Technology and innovation alongside the societal-cultural level, and go beyond energy aspects, norms, safety, smart and digitalizing technologies.

After the scale-reduction and fragmentation, there are the actions at the *meso*-scale (Sposito & Scalisi, 2020) of *synthetic recomposition* and *experimentation*. The aim is to relate the mentioned issues.

### 2.1 Inhabits the Fragility

As investigating scientific community, professionals and technicians, we are now called to respond to a widespread type of emergency: it is the *fragility* to which most of Italy’s built heritage is exposed. Looking back at the history of the Italian territory, we can see that, over time, buildings have shown an insufficient level of resilience in terms of seismic and energy efficiency. This situation forces a continuous and necessary updating of technical regulations and strategic planning; all this, to ensure safety conditions both structurally and in case of risk, in order to mitigate the damage (Palco, 2018). In Italy, more than 22% of buildings are in poor or very poor state of conservation and the construction sector is the most energy-intensive in terms of consumption, maintenance and habitability of the built environment (La Greca, 2016). The new paradigm is about digital technology applied to constructions, and it will completely change the way architecture is read and the resulting approach to inhabiting fragility. The explanation of the term “fragility” is quite simple: *fragile* is anything that causes harm or inconvenience to those who inhabit a space, whether in the case of a natural hazard or vice versa (De Capua & Palco, 2019). *Fragile* is a building that does not fit into an environmental context but defaces it, that compromises the lives of those who inhabit it because it is not very resilient or habitable.

*Fragile* is a space that compromises the quality of life of the occupant, a space that lacks the minimum services of *smart living*.

## 2.2 The Domestic Space between Circular Design and IoT

*Smart living*, is a concept that has permeated the entire construction sector in the last decade. It includes the different phases, from design to the construction process, from monitoring and maintenance to management by end users. The research activities concern the built environment that the scientific debate is, in this sense, currently analysing on, focusing on *circular design* and *circular economy*. By setting out the design process in three levels, three scales and three approaches that need to be connected, it is clear that the main trend is strongly linked to the possibility of making *smart* both processes and products of the “*house system*”. This concept is based on the idea that the use of technology enables the creation of environments that can truly improve and simplify the quality of life of the occupants. The current techno-scientific debate is investigating which tools can be considered *reliable* and able to respond to important needs, such as the *containment of renewable resources*; therefore, it is interested in measuring and containing energy consumption (the construction sector is today the most energy-intensive of all: about 40% of energy is used for the construction and maintenance of buildings) (Note), protecting people’s lives and environment, and last (but not least) quantifying the level of indoor comfort, especially in public buildings. Dwelling, in this perspective, is increasingly becoming a “*smart and sustainable*” interactive design that works through the continuous interaction between human action and technology using digitalized services, with the aim of significantly increasing the quality of life of the occupants. What makes the (inhabited) space intelligent is the *IoT* (Internet of Things), a system that allows the elements of the physical world to be connected via sensors (Ashton, 2009). The Internet of Things (IoT) in relation to smart living, can be described as the connection among domestic objects, the building envelope and structural material, with hardware and software platforms. All this is done through electronic and electrical devices, as well as sensors and actuators, that provide monitoring data on occupant well-being and building performance. Everything is done according to *the principle of circular economy*.

As the concept of *circular design & economy* is increasingly seen as key to the new sustainability paradigm, efforts to transition to it have intensified. Unlike the traditional *linear economy*, which is based on the so-called “*take-make-dispose*” tools (production-consumption-disposal), and which envisages the complete use of resources, the *circular economy* model promotes reparability, durability and recyclability (according to Kirchherr, Reike and Hekker, we have moved from the 3Rs - “*cradle-to-cradle*” - to the 10Rs: *recover, recycle, redeploy, rebuild, renew, repair, reuse, reduce, re-explore, replace*. These actions mark the shift from a *linear economy* to a *circular economy*). In fact, and to further reduce the scale, we are moving towards the concept of DfD “Design for Disassembly” (especially applied to the “house” system), based on reuse in several life cycles of building products, as it can reduce demolition waste (Akanbi et al., 2019). In summary, the *circular economy* aims to minimize waste by reusing, repairing, refurbishing and recycling existing materials and products, with

a focus on durable designs. In this system, *IoT* is considered an essential element, as it offers new opportunities for managing, monitoring and controlling processes and systems across different sectors, especially for the *home environment*. Developing a framework to facilitate the interaction between the *IoT* and the circular economy, will help the EU achieve the vision of an innovative circular economy where natural resources are managed sustainably and without waste, protecting biodiversity and respecting the planet.

### 2.3 The Scale of Residential Space

The monitoring and control systems belong to the management scale, while the DfD systems belong to the element scale: to fill the gap between the major and minor scales, it is necessary to add a middle link in the chain, as an intermediate scale. It assumes a value of strategic connection and has a spatial-typological character.

Following the same analysis criteria, we can also find three levels of investigation: *macro* (cities and neighbourhoods), *meso* (buildings) and *micro* (materials and components). In line with the previous, it is clear that research on the macro and micro levels is more advanced; the first is developing within the concept of *eco-city* (Van Berkel et alii, 2009), the second is developing within the material dimension and the circular management of the supply chain (Braungart, McDonough, & Bollinger, 2007; Lacy & Rutqvist, 2015), with room for improvement, thanks to ICT and *IoT* potentials; this also concerns DfD. The *meso* level has both an outdated update level and a different complexity, as each building is a single entity where each material has a specific life cycle and a long-term useful life that can generate uncertainties about future scenarios (Sposito & Scalisi, 2020). At these different scales, some projects have recently put into practise initiatives aimed to promoting the paradigm shift, of the building process, from linear to circular, and sufficient to be classified as *good practises* to which sector actors can refer (CE100, 2016). The focus of this research is on the *meso*-scale, which is the missing element in the general strategic plan.

### 2.4 Dwelling the Change

The *meso*, point of synthesis between *macro* and *micro*, and compromise between technical-technological aspects and the inhabitants' dynamics, coincides with the domestic space in the question of *dwelling*. It involves change and resilience, innovation and tradition, progress and sense of belonging. Indeed, to make the above approaches (DfD, *IoT*) effective and move circularly, it is necessary to operate in an environment predisposed to change. This is important to maintain the building in its entirety and in its parts.

For these reasons, the dissertation started with the *meso level* (brought into the discussion because it was identified as a key issue) and moved towards the smaller scale, defining a sequence of actions that designed a *resilient, flexible, adaptable and contextual* (Mussari, 2021) way of regulating/dialoguing-with the home space. Furthermore, considering these key concepts as paradigms of the future dwelling, it becomes clear that *IoT*, technology and socio-cultural aspects enter into a dynamic relationship only after an appropriate design thought. Finally, such a complex way of working

needs a strong *control of hierarchies* (Habraken, 1984), then a continuous management action. This allows the system to be both functional and circular, and appropriate to changing needs.

### 2.5 Academic Experimentation

To define N. J. Habraken as *one of the pioneers of circular economy* (Sposito & Scalisi, 2020), it implies his necessary commitment in rethinking the contemporary design process; the reasons are: the definition of the concept of *open building*, the methodology of *hierarchy* systems in design management, the involvement of different actors, the condition of man as the key among technology, technique and environment. Everything starts from people and everything comes back to them, and through their needs, it changes.

The designer becomes a constant presence in the life of the building and its inhabitants, working to change the domestic space without distorting its values.

The academic experimentation (Architecture Degree Thesis by A. Pierro, UniRC) started from the identification of a favorable situation on the territory. After recognizing the *skeleton* (which in this case coincided with the *Support* of Habraken), we used the methodology of the *Dwelling diagram* (Mussari, 2021). Accordingly, we chose the tool of Open Building to intervene in a reinforced-concrete tower structure, following some steps until the formulation of a possible scenario, like a *catalog*, to be given to the inhabitants with a kind of “instruction manual”.

## 3. Result

The diagrammatic tool which, as Habraken said, aims to methodically organize and control the *unpredictability of the results*, aims to find a strategy that, through some steps: *collects* the data about the environment, *detects* the trends and (partially) predicts the needs, *designs* residential solutions that look at the space, the people and the innovation, *initiates* a virtuous dwelling system. The latter should be in constant adaptation with the socio-economic-cultural development time and respect the paradigms. In other words, the diagram defines a **circular** system, suitable for the housing sector.

Here, we use this strategy through an experiment with Architecture Degree Thesis. We take as a study case an existing building, designed in the same period as almost all Italian buildings.

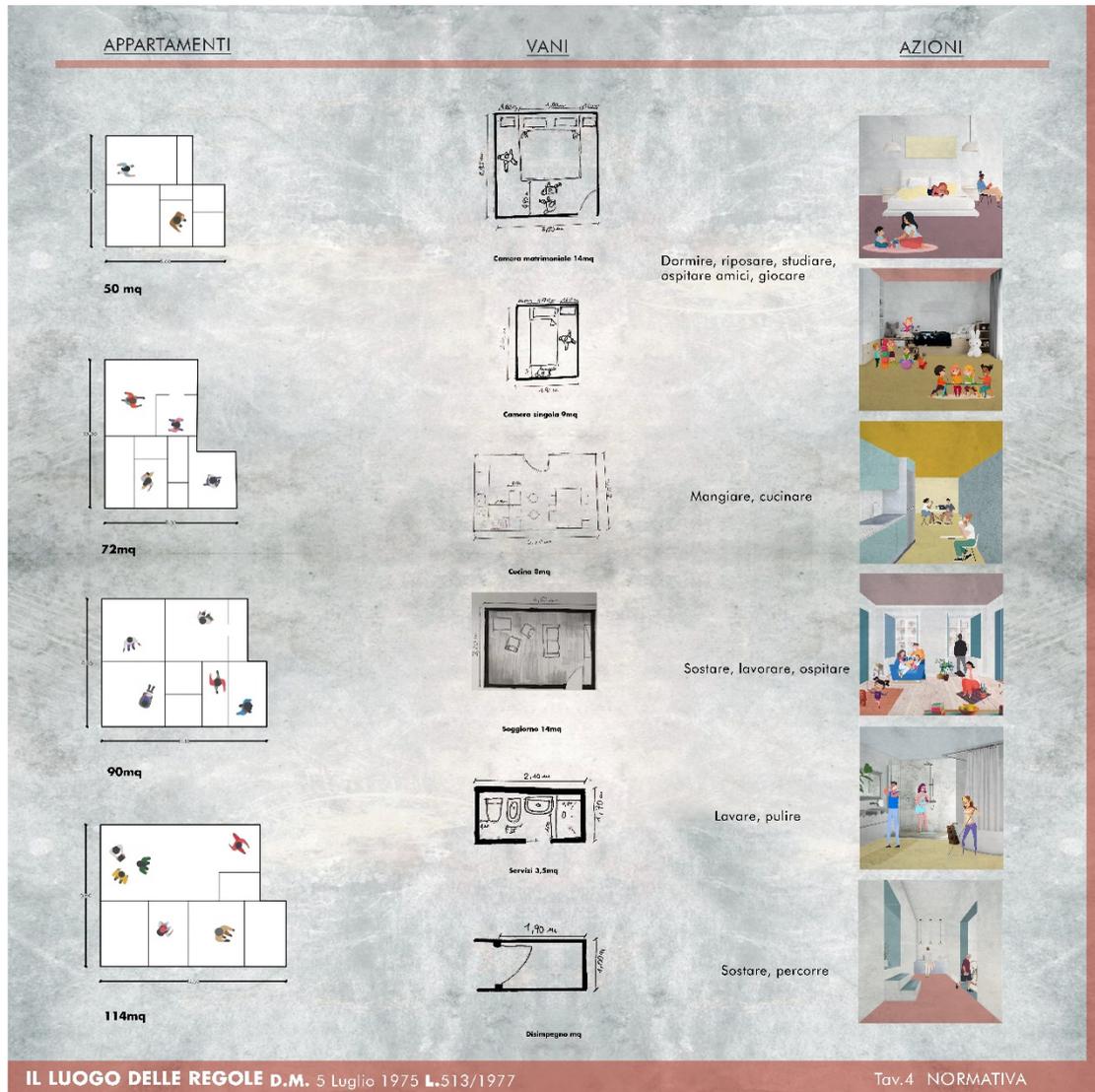
## 4. Discussion

The work was carried out by individuating a correct methodology. The aim was to conceive the design of *the new and renewed dwelling* and to guarantee good dwelling qualities. The reading key is a flexible approach that would make the space adaptable to the changing needs of people over time.

“In a context where we move between an imperfect system of land management and the tendency to conservation (or, rather, to *non-demolition*), the interventions to improve the quality of life can only concern the existing and/or the indoor, according to the widespread interventions and maintaining a constant representation of the housing and *lats*”: Stefano Garaventa (2013) expresses in relation to the legislation which, in its opinion, is outdated in relation to the current needs of **change** and

**development.** He points out that “the architecture of the interior of the building” is today the only one that can be modified and the only one that *indirectly determines the shape of the city*.

According to Garaventa, the question that guided the thesis was: *how* can we design, starting from the actions performed *in* the domestic space? The answer was to use an approach based on the presence of the *inhabitants* and on their relationship with the space, despite of the traditional use of standards (Figure 1).



**Figure 1. The Place of the Rules\_norms and Standard**

*Flexibility, adaptability, contextuality and resilience* are the identified paradigms, that came from a synthesis between the scientific literature and the Open Building theory. These paradigms led the entire project.

The expected result was a *catalog design*, a compromise between the authority of the designer and the participation of the user in typological-spatial terms.

The methodology was to translate the paradigms into spatial data, by designing different “sizes” measured in *dimensional ranges*; these, start with XS, intended for one person, and go up to XL, designed for coliving. Each size could be implemented with a *plus* (Figure 2).

We operated integrating the current normative with design thought on *the mutability of space in time*. We did it using *expansion, contraction and subdivision, disposal and integration* of “parts” of the house, without compromising the building.

The aim was to make the house *changeable* and to reduce the gap between *house and home*.



Figure 2. Apartment\_size M/M Plus

If the first problem was the *indoor*, the second was the *aggregation* of sizes, in relation to an existing shape and an existing technology. The choice, proper to Open Building and appropriate to **circular economy** and **circular design**, was to use dry systems, complementary to the traditional *Supports*; the following step was to define in advance an **abacus** of possible modifications (Figure 3). In this way we overcame the standard and the obsolete rigidity of subdivision into rooms—in the same rooms, during time. Particular attention was paid to rooms such as the *bathroom* and *kitchen*, ensuring that they were always adjacent to a cavaedium; In this way, the *pivots* around which the spaces rotate, have been functionally and spatially defined.



**Figure 3. Aggregation System-abacus**

## 5. Conclusions

The aim of the research is to test the proposed approach with the intention of verifying its appropriateness not only *ex novo* projects but also for existing buildings. This could be particularly interesting for contexts with low interest in demolition and reconstruction, as Italy.

The project, which until now has tried to reform itself, but only through circumstantial solutions, needs a rethink strongly focused on *circularity* at different but interconnected scales. These must also consider innovative and resilient inputs at the same time.

The choice focuses on the middle scale (spatial-typological), which represents the link between *macro* and *micro*. Only by solving this aspect we can proceed toward the *inside*; this is the current direction of the research. The next step will be to concentrate on a domestic object, on an element that, modularly composing and decomposing, defines the residential space through its relationship with the inhabitant.

This element, named *Re-xible*, wants to become a structural component for dividing up the interior spaces of the home in such a way that it sums up the philosophy of circular design. It is emblematic for the DfD (design for disassembly) approach. The research, focus of the Mediterranea UniRC formed by the authors, is also based on:

- *the use of recycled materials;*
- *the fulfillment of the requirements established by the LCA method;*
- *the possibility of having zero production waste and low levels of energy incorporated for its production;*
- *prefabrication aimed at easy assembly and disassembly and reuse* (Sposito & Scalisi, 2020).

These are the key factors in the creation of a sustainable product (in terms of energy input), where the building phase has a low environmental impact, placed on flexible and resilient living space. The requirement's satisfaction of ICT and IoT, is very important to improve the quality of the occupants' life.

The collocation of such an object like that into a *resilient, adaptable, flexible and contextual* place, could produce a spatial choreography that changes, ensuring wellness and a sense of belonging. A solution for *feeling at "home in space and time"*.

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#### Note

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