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HEAL - Housing for emergency and affordable living

Michela BAROSIO[1], Andrea TOMALINI[2], Rebecca CAGNOTTO[3]
(1) DAD Dipartimento Architettura e Design, Politecnico di Torino, Torino, Italy
michela.barosio@polito.it
(2) andrea.tomalini@polito.it
(3) rebecca.cagnotto@studenti.polito.it

Abstract
HEAL is a research work in which the aggregation of dwelling modules, designed to meet the new housing needs during emergencies, is designed and managed, using advanced digital tools.
Historically, cities have changed in response to threats or attacks, today more than ever, this transformation is clear. The concept of the house has changed, the experience of the recent lockdowns due to the pandemic has increased the already present trend towards a hybrid and multifunctional configuration, modifying the spaces of our homes in flexible environments. The forced stay inside our homes has led us to rediscover the outdoor spaces in their various types as a relationship with nature, although extremely domestic.
HEAL proposes a more responsive solution to the living space. The abacus of the modules allows to generate multiple configurations both in terms of settlement types and in terms of configuration of common and private interior spaces. The ability to compose, replace and vary building components in a digital environment allows detailed simulations of how the whole building can respond and react to external conditions. Plus, new shared spaces configurations can be tested, with the potential to decrease the transmission of infections.
Finally, the ability to semi-automatically transform the initial diagrams into BIM elements allows a precise control of the building components already in the early stages and, therefore, a considerable containment of the final costs.

Keywords: Emergency housing, Modular housing, Responsive architecture, Parametric approach,

1. Introduction
The present pandemic worldwide condition has shown up how much uncertainty is still characterizing our world and how resiliency mechanisms and flexible models are strategic. As architects and urban designers, we have decided to work on flexible affordable housing modules able to counteract different kinds of emergency situations, from sanitary emergency, to social needs, to climate disasters, to post war conditions. Modular housing has a rich tradition rooted in the Modern Movement experience as an architectural and building issue, but the related settlement issues still need a reflection. Considering emergency conditions as one of the drivers of city evolution, the research project HEAL tries to deal with urban settling flexible models through responsive architecture using a parametric approach.

2. Urban's form evolution in response to emergency context
Historically, cities had to transform following catastrophes and in response to different kinds of threats, so as to improve their own layout and prevent future attacks, as happened following the plague epidemic of 1300, the Cholera one of the 1800s or after the Great Fire of London [1].
After the Covid pandemic too, the cities will have to change to respond to the new raising needs. Following the new technologies, cities are in constant evolution, these changes are quicker and more abrupted especially after great crises. The Great Fire of London brought new building codes for fireproof constructions, infectious diseases, like tuberculosis, spurred the creation of wider green spaces and a search for sunlight and outdoor areas. Until the end of the 19th century, the fastest means of transport was the horse, to clean up the cities from the smell and disease the automobile was a success, this

allowed a new way of planning an urban centre and its mobility, with city enlargements and the relocation of shelters and hospitals in the outskirts.
During the present pandemic period, we are observing changing urban ways of living: the use of public transport is being reduced in favour of private transport, to avoid gatherings, even if we are trying to limit the use of fossil fuels, improving electric cars or scooters and bicycles, workplaces are becoming more flexible, and our own homes are always becoming our workspace as well. The concept of the cities divided into neighbourhoods, where you can live, work, shop and spend your free time within walking distances seems to be back [2].
This will also help in counteracting the phenomenon of gentrification, which has led less wealthy families to move to peripheral and less served areas, moving away from work and sociality areas, creating also an impact on the economic productivity [3], which was already on an important urban trend before the Covid appearance. Both of these attempts, to limit people circulation and to improve social mix and community neighbourhoods, might have an important impact on the evolution of the city's form, encouraging the regeneration of urban fabric through the development of new community spaces and flexible housing typologies.

3. Housing evolution in response to social changes

As a response to the pandemic condition but also to the relative economic crises and the smart working revolution, housing as well is undergoing changes. The house is the place where we must feel safe, if before it was the refuge from the chaos of the city now it also becomes the refuge from the virus, and it is hosting multiple functions. Therefore, it is inevitable that housing has to become more and more adaptive to better meet the needs of the occupants [4].
We have seen, during this pandemic, that the house has become the central pivot of the life of most people, it is no longer just the place where you sleep, but becomes an office, restaurant, school, space for recreation [5]. Most likely this pandemic will not be an exception (historically it is not), that is why the house has to become a more flexible and multifunctional place, to be able to reconcile the productivity of the individuals with their well-being. This requires innovative solutions for the small spaces of numerous current accommodation, such as the use of modular structures and movable walls, in order to make spaces adaptable to the needs of the user, but also the presence of open private spaces and storage spaces.
Therefore, we will also need to review the ratio between internal space and external space [6] both at the private and the collective level. To allow people to maintain a minimum of social life in a time where uncontrolled and crowded meetings have to be avoided, it might be interesting to develop private but collective areas such as the courtyards of buildings where a controlled and constant amount of people can gather. Furthermore, the private open spaces will also have the need to be in the foreground, in order to give the possibility to people to reconnect to nature when it is not available, even if in a more artificial and less wild form.

4. Housing modular design for flexibility

The modular design of the living space certainly makes it easier to create flexible and adaptable places. Modular homes can be produced much faster, being built in the factory and then transported to the project area.
The idea was developed in the 1930s following the first International Conferences of Modern Architecture. It was a period in which there was a pressing need for new homes and few resources to realize them. Le Corbusier began to formulate the idea of building houses in series, created in the factory as if they were aircraft or cars. To him, this way, the house would become a tool, accessible to all, healthy and safe [7]. Using the minimal spaces provisions forecasted by CIAM, made possible to have less waste possible and better efficiency of the space used. Then, the "house as a machine to live" and projects like the Maison Dom-Ino, Maison Citrohan and the Unité d'Habitation became models for a new generation of housing.
In recent years the modular and prefabricated design is returning to the scene, since this type of design allows to create new spaces of housing for emergencies in a short time, with low costs and low impact on the environment. For modular housing, more eco-sustainable and recyclable materials can be used and they allow to have less waste, since it is possible to control the production very precisely according to the needs of the customers [8]. Therefore, it is, possible to create building modules with a high technical level, but managing to achieve more accessible costs and maintaining flexibility in the design. Thanks to this approach, each module can be exchanged, modified, or eliminated in the final aggregation, without major problems. It is a very versatile type of design, which, depending on the needs, can be used for permanent or temporary installations and also allows a high degree of customization, both at a global level of the building and at the level of the single module.

5. Parametric approach to flexible housing and resilient city

Modular housing potential is related to its customization possibilities. In the Seventies of the last century Modular housing has been charged to be excessively rigid and not able to allow evolution of the house according to the evolving needs of the habitants during time. But nowadays Modular housing has no more to do with heavy prefab but with light structure and customizable configurations to manage which computational tools are required.
In addition to the multiple architectural variations able to satisfy a very wide audience of users, allowing multiple ways of living and a multiplicity of functions to be hosted at home, this research aims to deal with the urban scale trying to design aggregation models for modular housing in order to integrate modular emergency housing into the urban fabric. In this sense, emergency housing is not considered as a low quality, rigid and uncomfortable container which lands as a UFO landing in any empty space available. The HEAL project is aiming at conceiving a modular housing model addressing both architectural and urban levels.
We see a parallelism between the shift occurred in modular housing conception and the shift characterizing the “new global style”, also called Parametricism, as proposed by Patrick Schumacher [9]. For him current post Fordism age is based on customisation and complexity just like industrial modernity, where the modern movement developed the idea of modular housing, was based on standardisation and economies of scale. Nowadays the mathematics of Parametricicism seems to be the best tool to manage variations, hence to design variations and to produce them at a large scale. In this sense frame HEAL project is working on designing an abacus of facades’ elements compositions and finishing that can be combined with different typologies of private outer spaces in order to obtain highly personalised living units which production and aggregation is managed through parametric software.
At urban scale, techniques such as animation, simulation and form finding tools, as well as parametric modelling and scripting, have inspired a new collective movement with radically new ambitions and values. Starting from the concept of “continuous differentiation” [10] coined by Greg Lynn and Jeff Kipnis in the Nineties of the last century, parametric approach to urban design works by versioning and iteration process to interact with urban morphology and tectonic characters to avoid both mimicking and contradicting urban context. The final goal of the parametric managed housing aggregation is to contribute to urban resilience in term of housing emergency but also providing healing spaces at a block urban micro scale.

6. Housing for emergency prototype: design program

HEAL is a research project in which the aggregation of dwelling modules, conceived to meet the new housing needs during emergencies, is designed and managed, using advanced digital tools.
The project starts from the idea of designing affordable housing in a simple and fast way, setting up settlement principles in order to locate the housing complex in different areas of a city, matching several kinds of urban morphologies. For this reason, we have chosen the modular approach, which helps in building dwellings at a lower cost and faster, managing to have a certain degree of flexibility and customization. Thanks to the use of an abacus of modules, from which the users can choose the best solutions for them, from the layouts of the apartments to the finishing, new shared spaces configurations can be tested to suit many different urban and social conditions. The new private but somehow collective open spaces generated within the modules’ assemblage present a great advantage, in decreasing the infection’s transmission while offering the possibility of community life.
Designing in a digital environment helps to generate multiple different configurations in a short time and also allows to replace and modify all the components of the project, in order to better adapt to all the needed requirements.

7. Computational design: opportunities and threats in the case study

The housing prototype is based on the concentration of the project process under the architect responsibility, combining flexibility and freedom of expression of algorithmic design together with the control of information and data management, typical of BIM. The potential of algorithmic modelling in Building Information Modelling gives the designer the opportunity to autonomously programming a code, able in performing a certain repetitive operation, essential to the project, optimizing this way the entire workflow[11]. In this frame, the main challenge for designers becomes to translate the complexity of the real world into the simple rules and operations that will make up the algorithm on which Parametricism is based. This methodology used to design the housing prototype highlights the importance of the decomposition of design priorities into logical and creative solutions that can cope with even the most complex design problems [12].
The output of this process is the BIM model of a tower building in which it is possible to customize the position and type of housing solutions and to adapt the tower configuration to different urban morphological contexts.

The modelling process consists of several phases. Initially, the overall volume of the building is decomposed to identify the structural grid, then, through the definition of associative rules, the structural grid is filled with modules corresponding to the different residential functions (night area, cooking area, living area, sanitary functions, etc…). The developed algorithm defines local constraints, such as collisions between the aggregated parts (example: positioning of modules without overlapping but only juxtaposition), and global constraints, the recognition of some areas as more prone to some functions than others (example: identification of the staircase block), for the semi-automatic construction of the architectural object. The critical point encountered during the writing of the algorithm can be traced back to the definition of "universal" constraints that can support different types of construction. These rules, although banal for the designer, are difficult to translate into machine language in an environment that does not natively support many programming libraries.

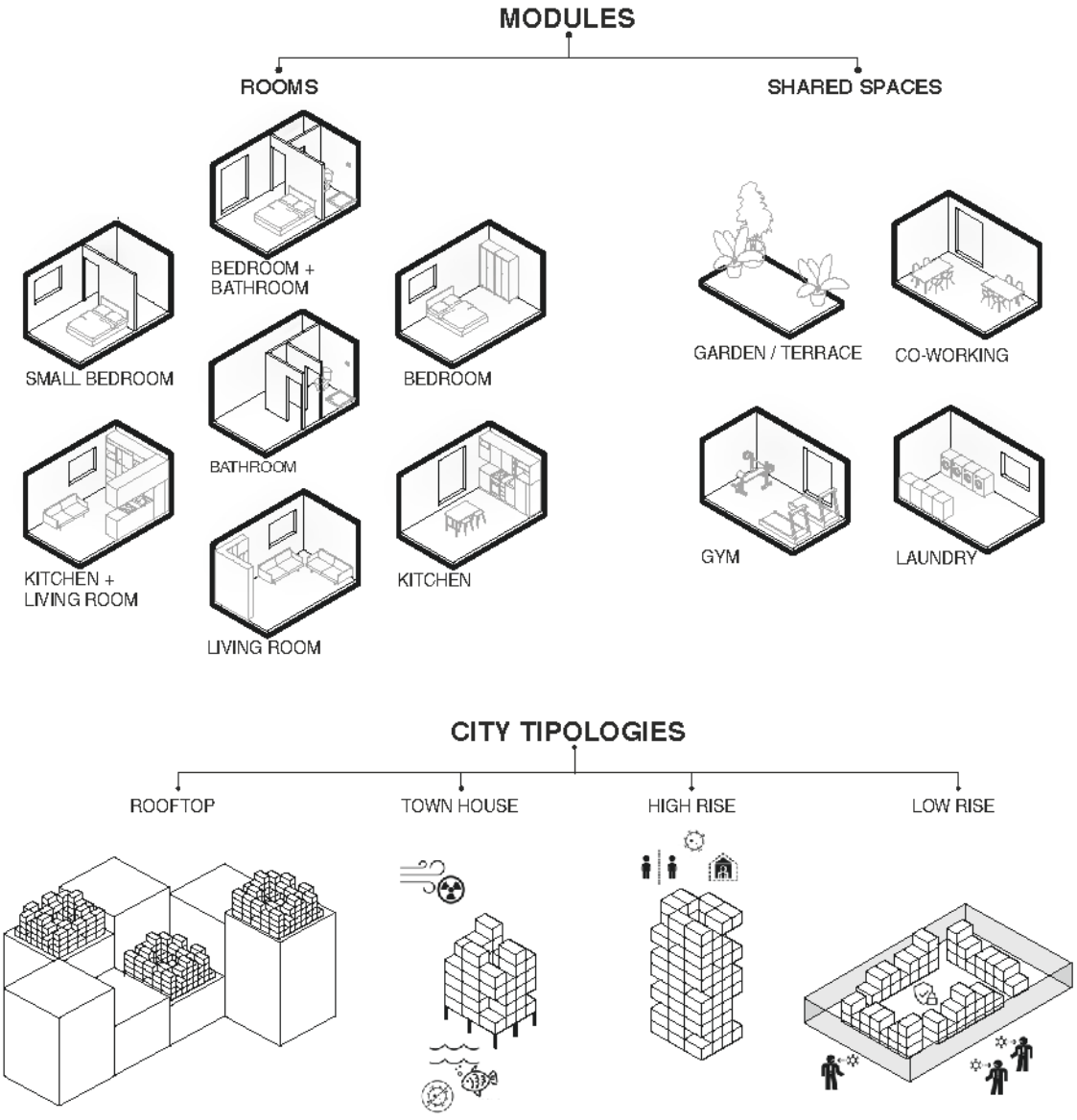

Fig. 1: HEAL Housing – Abacus of living modules and settlement typologies.

8. Responsive architecture: usefulness of simulations in emergency situations

The evolutionary and emergency states that characterize contemporary reality are no longer attributable only to extraordinary, exceptional and specific phenomena, but also derive from environmental transformations, social changes and the loss of specific building culture [13]. Design tools to plan adequate and timely responses plays a crucial role in terms of preventing human and financial losses [14] and would improve the resilience of even low-cost housing solutions.

In the building sector, the adoption of methodologies based on parametric systems has the advantage of guaranteeing greater quality and efficiency throughout the entire life cycle of a building; in the design

phase, conducting more accurate checks and simulations reduces errors and inconsistencies typical of the more advanced phases of projects carried out traditionally [15].
In emergencies this advantage becomes a real need if we consider the decisive importance that buildings have in people's lives.
Model management based on BIM systems and VPL applications would make it possible to visualize the potential and criticality of the project in a single environment.
In the VPL environment, given its nature, it is possible to convert design mechanisms to create flexible algorithms that can generate building schemes by hybridizing geometric information with the third information. Such schemes can be easily transposed into BIM applications as building components. The BIM environment manages the building components and can store the information used as input in the design, therefore the model managed in this environment can provide risk assessments by identifying the dependencies of different components [16].

9. Parametric approach: Possible applications and implementations

The case study is in its prototypal phase; therefore, it is only able to manage a few building types and further developments are necessary. The writing of associative constraints is to be optimized and it would be useful to be able to integrate environmental data for the optimization of the final architectural artefact.
However, it is crucial to emphasize that an effective response to emergency situations is a priority to overcome them. It is indispensable to develop systems to support the designer to facilitate the decision-making process. The advantages of adopting an algorithmic approach concern above all the affinity between the conceptual mechanisms of investigation and understanding of an object and the logical nature of the process, thus allowing greater control over the elements of the model and its information. It is possible to simplify the idea of an "algorithm" by likening it to a data flow in which each parametric component collaborates in the integration and modification of incoming information, resulting in a new list of output data [17].
Thanks to the introduction of Visual Programming Languages, the limitation of modelling is not related any more to the limits of specific software, sometimes a bit rigid, but has much more to do with the capability of the users, the designers, in translating functional need and formal requirements into simple parameters and algorithms. On the other hand, finding an effective algorithm presumes a profound knowledge of the object to be designed given the possibility of managing data that is not only geometric. A change in the methodology of model development must be considered, since the operations of rationalization of forms and decomposition of complex surfaces, which are traditionally thought of as operations linked to the most advanced phases, must become an integral part of the formal definition process from the early stages [18]. This implies, continuous updating and training on the emergence of increasingly sophisticated modelling tools. The challenge for the programmer might be to conceive friendly interfaces to improve self-learning.

10. Conclusion

This multidisciplinary research develops a multidimensional approach to healing housing and space design. Pushing modelling and algorithmic techniques to its limit, in order to constitute an effective support in managing a wide range of emergency situations. An underestimated opportunity given by algorithmic approach as a conception tool, is the opportunity to explicit the priorities assumed by designers and stakeholders allowing non-experts to share part of the decision becoming active in the emergency situation. This perspective broadens up a multitude of possibilities in healing space design conceived not as a top down approach but as a participatory process.

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CARMINE GAMBARDELLA

UNESCO Chairholder on Landscape, Cultural Heritage, and Territorial Governance; President and CEO of the Benecon University Consortium - Research Centre on Cultural Heritage, Ecology, Economy (Pegaso University, University of Campania “Luigi Vanvitelli”, University Federico II of Naples, University of Salerno, University of Sannio). Full Professor of Drawing at the Pegaso University and at the University of Campania. President of the International Forum ‘Le Vie dei Mercanti’ since its first edition in 2003 to the XIX edition in 2021. Editor and Founder of the series “Surveying is/or Project”, “Knowledge Factory” and “Architecture, Heritage and Design”. Component of the Scientific Committee of International A Class Magazine ‘Abitare la Terra’/‘Dwelling on Earth‘ (Gangemi Editor International Publishing). He covered various roles for the University of Campania, including the Pro Rector of Institutions, Academic Senator, Director of the Department of Architecture and Industrial Design Luigi Vanvitelli, Dean of the Faculty of Architecture Luigi Vanvitelli, Director of the Department of Culture of Design, Director of Doctoral School in the Discipline of Architecture, Coordinator of the PhD in Protection, Safety and Representation of the Environment and Structures and Territorial Governance, Coordinator of the PhD Program in Surveying and Representation of Architecture and the Environment. He is author of numerous scientific international papers, publications and proceedings on surveying and representation of the built and natural heritage.

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