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DESIGNING FOR URBAN RESILIENCE: SELECTED CONCEPTS FROM ARCHITECTURE TECHNOLOGY PRACTICE AND FROM SYSTEM THEORIES OF EMERGENCE

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Abstract *Environmental, social and economic global changes require a capacity to react at the city level, in a way that is effectively in the short term and adaptively in the long term. Cities have always faced complex interconnections and uncertainty scenarios, and the cities that have existed for centuries have demonstrated their resilience in facing them. Nowadays, the increasingly conditions of vulnerability and fragility of the built environment pose new challenges to timely and efficiently respond to the occurred change. On one hand, housing density and inhomogeneity, e.g. cultural and functional, are increased by the migratory phenomenon and by contemporary social demand for temporary dwelling, both of which are characterized by a time-based, unpredictable need. Moreover, the demand affects an existing housing stock which is, as yet, lacking in energy savings and comfort upgrades. On the other hand, economic needs transform cities often without a systemic strategy. It is still an underway process, even if the consequences of which are consistent in any post-industrial city. Therefore, it is required to rethink housing; to innovate in order to find adaptive solutions to properly feedback the complex needs generated by the environmental, social and economical changes. Considering resilience as a process that is not implying preconfigured and a priori solutions, Architecture Technology may contribute to the operational framework in both methodological and performance analysis by codifying requirements (technological, typological, procedural, functional) that can support resilient responses. In this paper, we explore the circuit of architectural design research and technological practice, adopting an interdisciplinary approach, inherited from the Theory of Emergence (Systems Theories), that help in developing a more comprehensive understanding of the housing-consumption cycle. Despite their different backgrounds, these diverse disciplines have the potential to contribute to a better understanding of how designed artefacts shape and are shaped by the contexts in which they are used. In what follows, we take a selection of concepts out of the Systems debates in order to identify a core set of attributes that can contribute to assess technological indicators for a more resilient technical housing design.*

1. INTRODUCTION

In our society, innovative technologies are constantly redefining disciplines and approaches, bringing about perturbations and discontinuities and inducing new hybrid concepts more resilient to the needs of sustainability. In this process, the concept of lightness has been more adopted by the disciplines, shifting its meaning from vision to necessity.
In this context of change, the “post-metropolis” [1] as well as the project of architecture are looking for more flexible technologies, urban planning methodologies and perspectives which may restructure the built environment and, at the same time, may meet with diversity the multiple needs that emerge. Indeed, new research perspectives are being shaped by the complex impacts of societal and economical behaviours on the built environment. The increasing conditions of a transitory lifestyle, as well as other variables as the climate change and migratory flows, are redefining the requirements of the built environment in terms of lightness, flexibility of use and adaptability.
Despite the knowledge framework of lightweight structures in architecture is not yet exhaustive (i.e. the degrees of safety, functionality, and comfort of the novel membrane-based lightweight architecture need to be measured and compared to other massive and traditional structures), this scenario opens to an experimental era that presupposes research and *open* results in the building process which may be more corresponding to the new and the unforeseen factor that is always related to it.

2. DESIGNING FOR URBAN RESILIENCE: AN OPEN APPROACH

This contribution comes, on one hand, from observing *ordinary architecture* and focusing particularly on the housing issue and, on the other hand, from the detection of some current trends that seem to steer the discipline of architecture away from its traditional forms.
Contemporary housing, or more specifically, certain trends in it that were spread by charismatic actors in the field – an example of which was represented by the proposal of the 15th International Architectural Exhibition, Venice Biennale, curated by the Chilean architect Alejandro Aravena in 2016 – seem to have shifted the attention on the theme of open housing from determining definitive forms to defining adaptable ones, open solutions and exploring their potential distinctive uses. This comes as an endorsement in favour of strategies and scenarios related to lightweight and thus tailored structures, which were considerably less diffused and rather marginalised in the past.
According to this perspective, projects are driven away from a purely formal nature and pushed towards a process-oriented one. One can notice this approach partly in certain empirical phenomena, such as the experiments conducted during the Modern Movement of the ‘60s which provided an insight into the applicability of the convertible architecture concept due to the production of prefabricated systems and components, that at the time were a novelty in the building construction industry. It is relevant to indicate however, that in the cases in which this vision was materialised by making use of massive construction methods (for example, based on reinforced concrete), it generated architectural forms which were rigid and difficult in terms of maintenance and transformability, but also constituted depersonalizing and anonymous urban settlements; on the contrary, in the experimental cases in which the concepts regarding flexibility in time were interpreted by applying reversible technologies and/or employing adaptable prefabrication in contexts with peculiar specifics (such as the explorations of Buckminster Fuller or Frei Otto), some forerunning examples of resilient habitats emerged.
Nonetheless, it cannot be denied that, in the last twenty years, production chains in the building construction sector have been directed towards the industrial design of assembly and fabrication of components, as opposed to a modular design of building systems. This was made possible due to the introduction of *discontinuities* related to the potential of designing through digital interfaces and virtual building physics simulations, which allow for an integrated understanding

of components and structural behaviour already at the phase of design, thus completing the prefabrication phase in the virtual environment. The variation of production chains has also made the whole process of architectural design and construction considerably shorter [2]: fewer subcomponents are fabricated and integrated with each-other, in order to compose kits (EU 305/2011) that would shorten the supply chain even in cases of complex projects, in which the sequence to be followed would be fabrication, delivery and a simplified assembly process on site [3].

2.1. The Systemics as the conceptual framework of the contemporary urban housing

Concerning the architectural process, the tri-pillar challenge of sustainability (environmental, social and economic) requires multi-scalar, dynamic and inter / multi-disciplinary approaches and methodologies that detect emerging behaviours in different areas, to be transposed in the design process of technological performances and function values of the built environment.
The design process unfolds in a multidirectional way from the micro to the macro scale and vice versa, collecting on one hand issues that emerge from the urban and building scale and, on the other hand, transferring concepts and methodologies by analogy from other disciplines.

The Systemics and the application field of urban systems can be linked together if architecture outputs are defined and analysed as regulation systems that connect physical, social and economic subsystems. In the 1970s, a first systemic approach [4, 5, 6] tried to bring near architecture and production chains in the building sector: this approach, however, had been based on a linear interrelation between needs, requirements and performance, and had being focused more on the functional aspects of architecture, rather than on more qualitative aspects.
The urgency to implement the systemic approach derives from the contemporary challenges induced by the study of complexity (i.e. the need to maximize the interactions between users and the design and construction phases in the building sector). Indeed, the systemic approach and, in particular, the trans-disciplinary concept of emergence, is also relevant as an interpretative/ cognitive model, and not only as a scientific one.

The literature reports that Systemics derives from the *Systems Theory*, which includes the traditional Control Theory, Systems Analysis and Cybernetics [7]. Specifically, the *Systemics* is the conceptual extension of the General Theory of Systems: it is a methodological corpus based on the concepts of *system, interaction, emergence, inter/trans-disciplinarity* and it studies the behaviour of a system through modelling and analogy. The *Systemic Approach* refers to the general methodological framework of the Systemics and it allows to identify, considering a problem, the *interactions*, the *levels of description* (at the micro, meso and macroscopic level), the *emergence processes* and *the role of the observer* [7].
The key concepts of the Systemics [8, 9, 10, 11] can be summarized as follows:

- a system is different from a set of elements because its components interact, and the behaviour of one affects the other; it follows that the systemic properties are different and not deducible from those of its component elements. So, for example, the economic trend is not given by the sum of individual behaviours, but by their interaction;
- the observer is not intended as an external element, but as an integral part of the process;
- the level of description and the boundary conditions to the analysis of the system are referred to the cognitive model assumed by the observer.

This paper focuses on the *Theory of Emergence* which has broadened the application field of the General Theory of Systems. While the latter limited its interest to the processes of interaction that transform a set into a system, the Theory of Emergence studies the continuous processes of acquisition of different, but coherent, systemic properties by a system. Examples of these are the properties of swarms, flocks, anthills as well as those of car traffic and signals. The systemic properties can be considered in terms of *forms* (even the *environment*), behaviours, failures, consumption, robustness, etc.

The concept of Emergence is related to the coherent process of establishment of collective behaviours of organized or self-organized entities.
Indeed, the key concepts related to the Theory of Emergence are:

- the Emergence is a process of formation of new – from the observer's point of view – collective entities, organized or self-organized, and established by the coherent behaviour of interacting elements (i.e. the coherence can detect the emergence of industrial districts or urban aggregators).
- the Emergence is a process that has to be considered dependent on the observer. Indeed, the observer is part of this process because s/he represents the cognitive model to detect the coherence itself.

Referring to the role of the observer, it is stressed that: i) the collective properties emerge at an upper level of description to that used for the components; this different level of description requires a different cognitive model, adequate to detect the establishment of the coherence of collective behaviours. (i.e. macroscopic rather than microscopic); ii) the collective properties are detected as new phenomena, even unexpected, by the observer dealing with the assumed cognitive model. Examples of emerging properties are work safety, use of urban furniture, etc.
Furthermore, it is relevant to notice that the Theory of Emergence conceptualizes the use of a system not necessarily in relation to its functions: stairs can be used as seats, streets for unforeseen evacuation, buildings as storages, etc. The interaction in these cases is between occupants and housing structure and between occupants themselves.

2.2. The Building system

Referring to the conceptual framework of the General Systems Theory and the Emergence Theory, which could be the operational framework of the project of architecture in the built environment, and which could be its impacts?
In terms of the Systemics, the built environment emerges from a system of interacting buildings by means of infrastructural networks, i.e. streets, and occupants' behaviours. The building system acquires several systemic properties that are different either by nature and level, i.e. disposal consumption, energy consumption, safety.
In literature is also pointed out that, from a systemic point of view, the properties of the elements interact with each other and that the properties of one element actually influence the ones of the others. Applying this approach to the building system, the properties of the building influence the properties of the interacting elements, i.e. the occupants' behaviours, and vice versa. It should be noted as the properties of the building system refer to its technological subsystem, as well as its functions (i.e. a school, a stadium, a prison, etc.).
In this sense, some authors introduced the concept of "implicit design" by which "l'architettura esercita una notevole influenza nella sintassi dei processi sociali dell'abitare e del vivere contestuale, e viceversa." (architecture has valuable impacts on the social structure of living issues.)[1] [10, 12, 13, 14]. More specifically, the syntax of the space considered both in terms of functions and technological components, is assumed to induce, or to make emergent, some behavioural properties. For example, a urban furniture could inhibit for parking, designing common spaces could foster social relations, and so on. This topic refers to the Environmental Architecture[2], object of a more recent interdisciplinary study and which deals with the emergence

[1] Translation by the Authors.
[2] «Environmental psychology came to the attention of architects some years later when focusing on relationships between architecture and psychology, originally developed in the United States to reduce criminality and make prisons more suitable.» [15]

processes that induce collective behaviour in social systems and the syntax of the space generated by architecture [11, 16].
Moreover, it is fundamental the role of the occupant which is very similar to the one of the systemic observer: it is an active role that defines the architectural device by using it [17]. Thus, for example, the entrance to the Museum of Contemporary Art in Barcelona (MACBA) in Spain is known to be one of the city's Skate spots, thanks to the long granite benches and the difference levels of the square that are used by the skaters.

The building system is therefore the system of technological devices and collective behaviours that define and establish the built environment; the operational framework of architecture is the built environment that is determined by the interaction of physical, social and economic systems.

As already mentioned, the traditional design process, meant both in the restoration and in the new construction, represents linear input-output relations as a consequence of the technological design relation between needs and requirements and thus avoiding to refer to a more complex structure of relationships made by uncertainty and unpredictable scenarios.
Instead, assuming a systemic approach, it is fundamental to refer to that complex structure in a way that is feasible to the phases that occur in the design and construction process. In the following scheme (Fig. 1) connections to cultural and economic values and emergent behaviours are introduced in parallel to the linear logic of the project and which would be conditioned by the decisions taken by the traditional sequence (needs-performance).
According to this vision, every environmental phenomenon is an open system and, as such, it is subject to a continuous exchange of matter, energy and information with the interacting elements; the emergence of new structures depends on the conditions of stability / instability of the urban system according to random facts and non-linear trends.

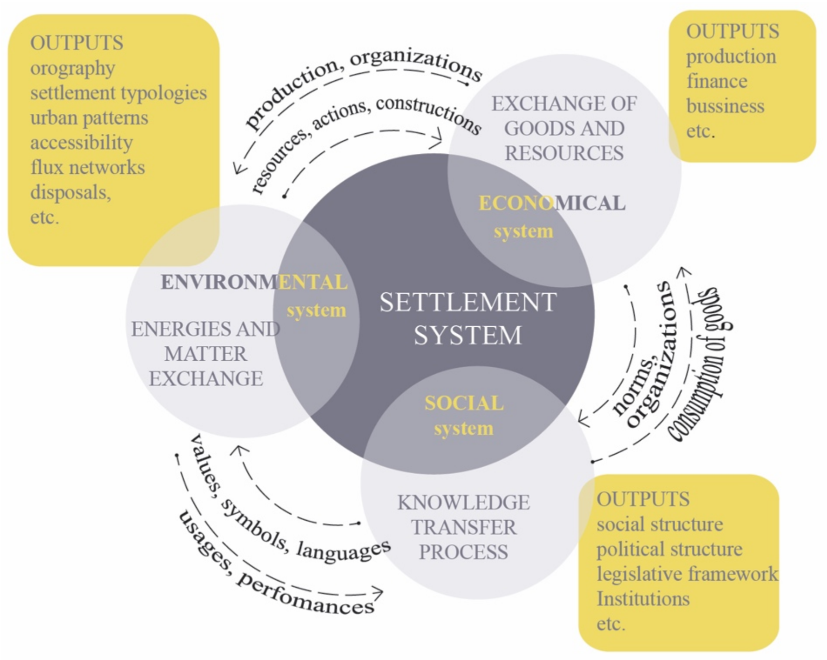

Fig. 1, Observed *Systems – mutual relationships*
Developed by the Authors on the basis of: Di Battista V., La concezione sistemica in Architettura: scenari di sviluppo, in *Architettura e Approccio Sistemico/ Di Battista V., Giallocosta G., Minati G., (ed.),* Polimetrica, 2006-2007, Milan, p. 87 [12].

The following scheme (Fig. 2) deepens the linear design process on the built environment, either

for conservation and transformation purposes, and shows the interaction of the three dimensions of values (e.g. social, economical and cultural). It aims to illustrate the social and economical needs of the observed system, by means of congruence/ incongruence indicators; and it aims to combine these indicators with the cognitive model of the observing system (i.e. institution, occupant, designer, etc.). This is, namely the observer's point of view, made by the social and functional models, the economic opportunities, the degree of collective awareness of the value and collective participation (cultural model), all compared with the required performances of the building system.
The decisions that derive from the congruence/incongruence indicators and that are conducted through different levels of description and thus knowledge, refer to conservation and transformation actions.
This coherence, which is irregular and discontinuous in relation to the assumed connections between the framework of needs and values, translates into a logical scheme that entrust the subjectivity of the needs framework to the cognitive model assumed by the observing system. This definition explicates the framework of values that emerges from the observed system and that acquires coherence only through the knowledge-evaluation exercised by the observing system.

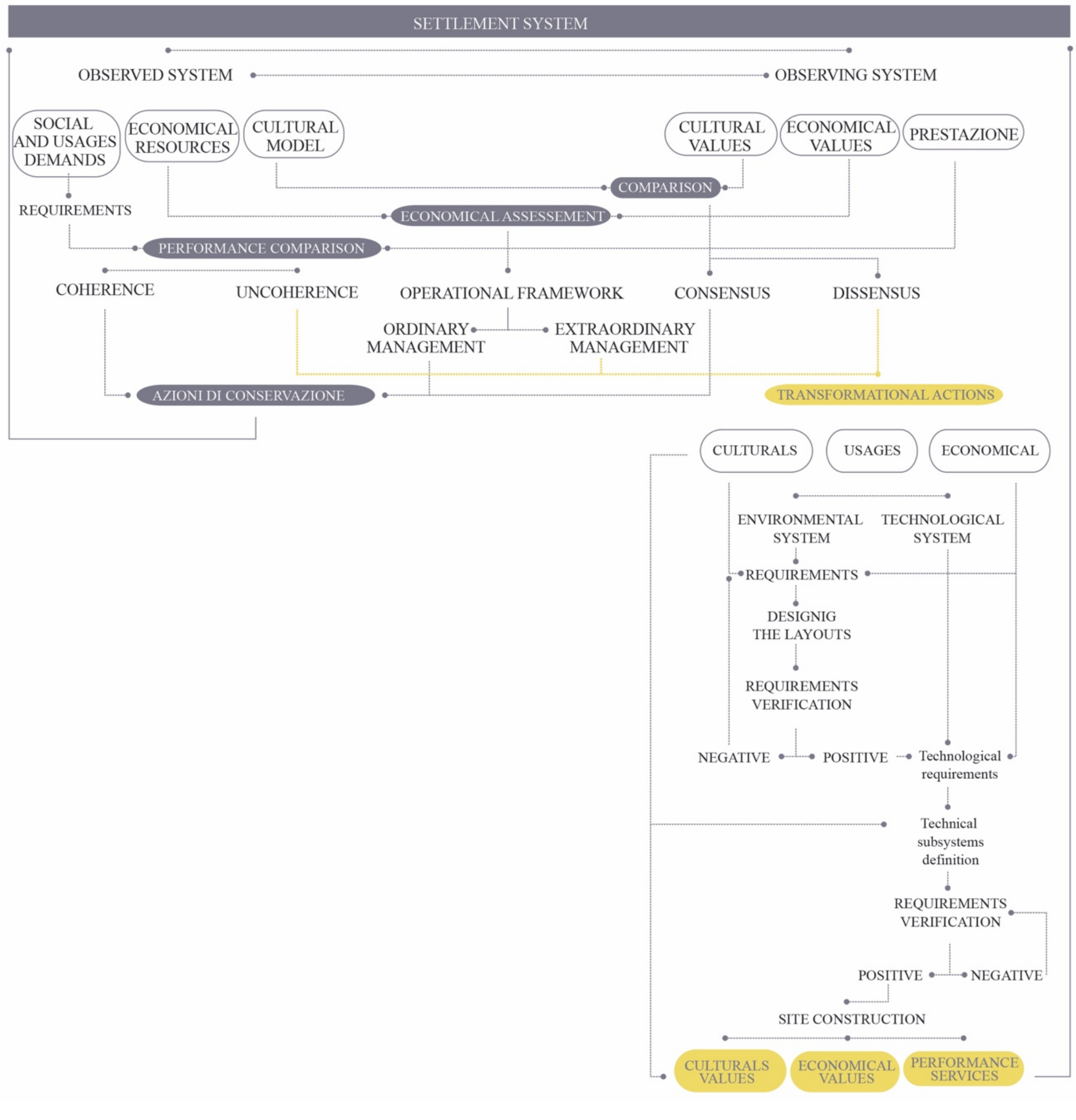

Fig. 2, *Linear and non-linear relationships in the architecture designing process.*
Developed by the Authors on the basis of: Di Battista V., La concezione sistemica in Architettura: scenari di sviluppo, in *Architettura e Approccio Sistemico*, Di Battista V., Giallocosta G., Minati G., (ed.), Polimetrica,

2006-2007, Milano, p. 88 [12].

As Di Battista mentioned, "l'approccio sistemico all'architettura permane utile a estendere la lettura delle relazioni, a coniugare il circolo ermeneutico conoscenza-azione-conoscenza e a introdurre l'avvedutezza diacronica della permanenza (memoria) e dell'immaginario (attesa e proiezione futura) attraverso la considerazione temporale dei processi e dei lungi cicli di vita del costruito"[3]. In other words, the systemic approach doesn't represent just a strategy for the architectural design process, but also a multi scalar and open knowledge process. It is potentially a method of acquiring knowledge of the possible scenarios that can emerge as collective behaviours induced by the project actions.

2.3. The emergence of the social behaviours

In the last years, new social and economical aggregators have arisen featuring innovative objectives, organizations and structures compared to the traditional [18]. The Italian legislation is in the process of implementing the norms according to these emerging trends: it is therefore in this sense that the Riforma del Terzo Settore (Legge di Riforma 106/2016) reorients the operational and legislative framework of the Third Sector by introducing, for instance, the social impact as validation of the *evidence-based policy* [19].

The informal statements emerging at the micro and meso level of the social society are driving the economical structure to more Non-formal organizations based on social relationships. Hence, at the macro scale is meeded necessary to bolster the new social structure. The City of Bologna, for instance, set up the "Regolamento sulla collaborazione tra cittadini e amministrazione per la cura e la rigenerazione dei beni comuni urbani" (2014) to grab and formalize the private citizens' initiatives about the collective management of public spaces.

Some experts [20] suggest to detect the congruence/ incongruence of the observed system by introducing three sub-categories: the Formal/ the Informal/ the Non-formal [4]. The latter refers to intentionality even where there is no formalization, and it introduces processes without certifying them. Pais [20] summarizes some key concepts about the three sub-categories, independent from the organizational framework:

- the aggregation by multi-functionality (i.e. expertise, professionals and spaces: maker spaces, fab labs, etc.);
- the enhancement of the g-local scale, also due to the introduction of technological discontinuities (e.g. social streets);
- the spread out of (connective) actions of people connected through networks, instead of collective action;
- the social entrepreneurship as a driver to overcome the structural inertia of the labour market.

Furthermore, the relevance of the emerging urban phenomena is at the international level. The concept of the post-metropolis [1] is largely investigated by the Italian research project of national interest "Post-metropoli" 5 [22]; the post-metropolis is assumed as the cognitive model to detect urban phenomena, rather than as a new form of urbanization.

[3] Translation by the Authors: "The systemic approach to architecture is relevant in order to expand the analysis of relations and impacts around architecture, to conjugate the hermeneutic cycle of knowledge-action-knowledge and to introduce the diachronic cautiousness of permanence (memory) and of the imaginary (expectation and future projection) throughout the life-cycle analysis of the built environment."

[4] «Per esempio, nel campo della formazione, la f. formale è intenzionale, programmatica e sfocia in una certificazione o convalida; la f. informale non è strutturata in termini di obiettivi di apprendimento, di tempi e risorse, spesso non è intenzionale. La f. non formale è intenzionale perché indica attività intenzionalmente orientate a uno scopo, all'interno di contesti progettati per altri obiettivi.» [20]

[5] Progetto di Ricerca di Interesse Nazionale 2010-2011 PRIN: "Territori post-metropolitani come forme urbane emergenti: le sfide della sostenibilità, abitabilità e governabilità" (Alessandro Balducci, Valeria Fedeli – Politecnico di Milano) [21]

The concept exceeds the traditional dualism core-periphery to explore the impacts and the emerging balances related to the concept of “peripheral urbanization” [1]. It is worth that investigating the constraints /opportunities of peripheral areas is an issue for dealing with Peripherality, overcoming or avoiding Peripheralization. It is mentioned that Peripherality/ Peripheralization are not synonymous: while the former is a condition, the latter is a process (marginalization). The post-metropolis dips into the non-formal erosion between urban and non-urban, and investigates the new patterns of (sub) urban. In this sense, the concept of post-metropolis assumes the value of the urban defined by Friedmann as «*no longer simply a specific place – though it is as well – but a global meta-process of continual change*» [23]. The post-metropolis concept induces to analyse the relations more than the physical boundaries between urban agglomerations by means of multi scalar convergences [1].
Concerning the Governance, the outcomes are particularly severe[6]: the national geographies produced since the second post-war period to today appear dated to report the economic and cultural reorganization of space [22].
Furthermore, the Metropolitan City (Legge Delrio 56/2014) consolidates the historical, geographical and environmental patterns and gathers 18 millions of inhabitants to establish a more systemic approach to the urban agglomerations. In this context, the emerging processes that are reorganizing the urban areas in coherent and complex networks have not yet found adequate representations and levels of description [26].
However, the value of the “Post-metropolis” project is to investigate the iterative relationship between several spatial matrix and the reorganization of functions and uses of urban geographies, validated by means of the assumption that connective and non-formal actions anticipate the formalization of Institutions and organizations.
According to Balducci, if in the twentieth century the urban question was related to the right to the city, in the post-metropolitan context the urban *equity* has blurred contours. From new social peripheralities (i.e. migrant flux) to the non-formal erosion of urban and non-urban geographies, the Post-metropolis claims a multi scalar convergence of multiple urban levels.

Milan is the more representative Italian city in terms of Culture and Creativity [27] and it is among the first five European large cities[7] (inhabitants > 1.000.000) that most represent the economic and social development of culture.
Going further, what makes Milan a representative model to be analysed? i) Milan is almost the only Italian city to has experienced a real phenomenon of *metropolisation* since the second post-war period; ii) most recently, it has experienced a *regional metropolisation*; iii) even before these two urbanization forms, the city had been structured following a polycentric and plural model [22].
In Milan, the built environment is within the average of Italian cities whose residential stock dates to the decade ‘60-’70, with the highest concentration in the peripheral urban areas which are the densest urban areas in term of population (Tab. 1):

Location	**n. Houses**	**%**	**n. Inhabitants**	**%**
Historical centre	3.423.160	17,34	8.479.659	15,07
Modern	2.038.091	10,33	5.188.268	9,22

The research aims to “sull’investigazione delle dinamiche storico-geografiche di distruzione creativa che producono trame e percorsi dell’urbanizzazione contemporanea. Dimostrazione empirica della varietà delle situazioni urbane e di come il concetto di metropoli, con le sue implicazioni socio-economiche e territoriali, e con la sua visione centrica e gerarchica, risulti inadeguato a interpretare le forme dell’urbanizzazione contemporanea. In particolare nella post-metropoli dovrebbe osservarsi il fenomeno dell’appiattimento e la dilatazione del gradiente di densità della popolazione; si assiste cioè a una crescente convergenza tra densità urbane e suburbane che, diversamente dai tradizionali modelli centro-periferia, suggerisce l’emergere di una nuova condizione urbana.»
[6] «Among the many effects of this extended form of regional urbanization and its associated scalar restructuring has been an aggravated crisis of urban and regional governance.» [24].
«The old administrative and political geography of national governments around the world have been among the slowest geographies to change over the past four decades, especially when compared to economic and cultural reorganizations of space». [25].
[7] The survey had been carried out on a total of 168 cities in 30 European countries.

Centre				
Pheripheries '60	**5.120.621**	**25,95**	**14.975.289**	**26,62**
Pheripheries '70	3.733.030	18,91	12.158.956	21,61
Pheripheries '80	1.935.002	9,8	6.278.139	11,16
Total city centre	5.461.251	**27,67**	13.667.927	**24,29**
Total pheripheries	14.274.662	**72,33**	42.595.887	**75,71**

Table 1. The pressure of the urban peripheries in Italy (Data Istat 2010).

2.4. Lightweight technologies in architecture and the socio-economical impacts of the contemporary housing

It is a fact that the contemporary housing is increasingly characterized by the need for flexibility, build-out speed and dematerialization, as well as by the criteria of environmental efficiency, comfort, durability and life cycles of the material components. For over fifty years, architects have been constantly involved in a continuous debate on redefining their role in relation to the new living spaces, in the light of technological advances, but also thanks to the legacy of thought that defines "architettura senza tempo"[8] the result of the built environment, which is not self-referential, but is an open system, in which the interaction of social, relational and economic conditions define in a *continuum* the surrounding environment, through incremental design actions.

In this timeframe, in parallel with the discussion on the role of architecture in redefining the built environment, a particular branch of architectural design oriented on technological performances focused on achieving disciplinary advances in the materials and building processes of dry-assembly construction, in order to recover existing built assets, as well as to restore built heritage in terms of energy efficiency and acoustic performance. This has also shaped new ways of carrying out the design and construction processes by means of, for example, the mechanization of the construction site through dry assembly or joinery methods, that do not make use of mortars or cement-based binders [9] [1].

In the last years, technological research in the construction sector has reached even antithetical results in comparison to the initial explorations of Buckminster Fuller and Frei Otto: compared to the prefabrication of the first phase, the today's production chains allow a larger assembly process by means of fewer subcomponents integrated to compose kits [29].

Moreover, the different composition of increasingly optimized and performance-based products promote the attainment of more and more responsive technological packages to specific needs. The rigid modularity of the initial prefabricated solutions was a closed system, not convenient to design and fabrication necessities. Instead, the benefits and impacts of a design and a fabrication process by components is spreading out over the construction process (i.e. dry assembly or joinery systems) and over the life cycles of the building itself. It is worth to notice that this renovated practice in the building sector is more an incremental innovation rather than a disruptive innovation as it was for instance the introduction of the reinforced concrete in the early twentieth century. Beside ensuring a wider expression in terms of architectural design, the *off-site* construction systems reduce the use of materials through lightweight fabrication processes which

[8] We refer, among others, to Ratti, who argues that «gli architetti progettano la domanda, non la risposta» and identifies in the open-source «la modalità di un nuovo processo progettuale in cui l'architetto è l'intermediario delle esigenze, dei bisogni, dei desideri dell'utenza, che diviene abitante. L'architetto è un creatore di schemi aperti più che di soluzioni.» [28]

[9] «In questi progetti, si potrà constatare come la richiesta sociale abbia innescato un mutamento della variabile d'uso e non si è proceduto alla scelta, a volte inerziale, di tecniche costruttive a umido in favore di una longevità della costruzione non meglio precisata e nemmeno si è andati ad alimentare la retorica delle tecnologie leggere mediante giustapposizione meccanica e demistificando la tipica prerogativa della tecnologia leggera, ovvero la flessibilità d'uso, scambiata come sinonimo di precarietà della casa. » [29]

allow a lower energy consumption by assembling performance-oriented and high-tech components. Despite they do not work by thermal inertia as they are not massive, the lightweight technologies optimize the energy efficiency by overlapping three main discontinuous layers (e.g. the primary structure, the secondary structure and the partitions) that have to fulfill optimum cutting performances. Their overlapping structure is the guarantee to avoid vulnerabilities (thermal dilatations, heat bridges, static inefficiencies).
Moreover, these structures can be modified, quickly maintained, dismantled and reused in other contexts, thus creating cyclical processes during their whole life cycle. Reversible design allows the building deconstruction once the building will be abandoned, with multiple benefits compared to traditional demolition processes, such as the disposal costs. [31]
Against this background, it is possible to outline a set of technological requirements that allows to change the usability of buildings system and their technical components:

- ADAPTABILITY, intended as the definition of a set of adaptable elements, i.e. the construction technology. Or also intended as the definition of adaptable categories, such as the
- CONSTRUCTION REVERSIBILITY, that represents the passage from the product oriented design to the process oriented design;
- ASSEMBLY, conceived as the capability to connect technical elements, but also specialized knowledge, through a series of input/output sequences;
- SPECIALIZATION;
- FLEXIBILITY;
- MAINTAINABILITY;
- REVERSIBILITY;
- LIGHTNESS, intended as the minimum use of material without losing efficiency and form clarity.

Referring to the lightness requirement, it’s necessary to underline that, in architecture, lightweight technologies (membrane-based structures, minimal mass building systems, composite materials etc.) have been considered only recently as building materials. When applied in traditional construction processes, lightweight technologies allow to obtain important advances in terms of amount of materials and construction reversibility. Commonly used for temporary structures, lightweight technologies have been spread due to recent progresses in computational tools and digital manufacturing. In a post-industrial production era that aims to design components instead of fully-equipped modular systems, lightweight components are used both in refurbishments and in new constructions, according to criteria of lightness; moreover, they enable to realize minimal mass structures that are easy to erect, in accordance with the contemporary, transitional living moods. Finally, lightweight technologies are more sustainable and environmental friendly than massive materials, in line with current environmental policies.
The design with technological components implies an Open Building Process [32] which lets to achieve the social, economic and environmental needs for a sustainable built environment. Indeed, the Open Building Process enable the user (a person that lives the space and determines it) to define the most effective, appropriate solution in each specific time or context.

3. CONCLUSIONS

In the current scenario of post-industrial production, the building construction is a hybrid process between the standardized industrialization (the products) and the singularity of the final result (the projects). The systemic approach is proposed as the methodological framework for supporting the reset of the post-Fordist production process towards a more flexible manufacturing

one, that could evolve in a feedbacks cycle in relation to *off-site* and *on-site* sequences. The production of a *tailored* output both in terms of the project's needs and technological/ functional flexibility and adaptability, is linked to such indicators as cost reduction, efficiency, waste reduction and re-use (i.e. both in the transport and assembly phases).
However, it is still relevant to focus on how efficient is the prefabrication in architecture. Is there an alternative and effective way to improve the energy efficiency of existing housing stocks, without adding massive materials and avoiding costly on-site construction techniques?
Recognizing the fact that non-negligible waste factors are still identifiable also in the supply chains of prefabricated technological systems [33], the use of lightweight technologies seems to guarantee a greater level of flexibility and technological/ functional adaptability both in the new constructions and in reconstructions (as, for example, the low-cost recovery of industrial buildings), thus managing to better respond to the needs of contemporary housing.

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