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Architectural Transformative Potential in Existing Buildings

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Abstract: The waste of land is an issue for sustainability, and the literature on adaptive reuse frequently refers to its untapped *potential*. The present research aims to provide a methodological framework to define, decode, and assess the concept of *Architectural Transformative Potential (ATP)* in existing buildings. The study also aims to widen the boundaries of architecture, considering the process that shaped dismissed buildings and the *option-value* of design. The research framework is the *post-functional era*, where the built environment requires classification following morpho-structural characteristics. The paper suggests *embodied energy* and *morpho-structural flexibility* compose *Architectural Transformative Potential as primary elements.* The open function defines the ATP as the sum of embodied energy in the existing structure and leading open options in design practice. The findings should make an essential contribution to the field of adaptive reuse, evaluating the impact of further use options.

Key words: transformative potential, embodied energy, flexibility

1. Introduction

Many authors highlight the reduction of energy footprints as a generative power in the architectural design practice [1-3]. The sustainability issue is one of the triggers of adaptive reuse strategies. Such strategies frequently involve the release of untapped potential, as already present in the existing built environment [4-5].

The current adaptive reuse approaches focus on the concept of untapped potential, even if a complete definition concerning its meaning is still lacking.

The present paper defines the concept of *Architecture Transformative Potential* from an interdisciplinary point of view. The *ATP* is identified and addressed as a useful tool to evaluate dismissed buildings.

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The post-functional era is the boundary system of the present research. This thought arises in a novel classification of the built environment. This classification is independent of the functional type of buildings and based on formal and structural characters only.

Stemming from the root of the term potential within different disciplines — as Physics, Philosophy and Social Sciences — the concept of potential is defined both in a theoretical and an operational meaning, highlighting its main behaviours [6, 7].

Real estate studies quantify the amount of Adaptive Reuse Potential (ARP), and the capability to change (Flex) as the results of indexed parameters [8, 9]. However, indicators and fixed metrics define these concepts. The present research focuses on an open formula instead.

Starting from the 17th century, the term potential has continued to spread, making a significant increase during the 1960s. References to this potential are strongly present among hard sciences. The exploration

regarding the concept of potential are numerous, but it is still not clearly defined in the framework of architecture. The literature — especially the one concerning interventions on the built environment — considers the untapped potential in existing buildings as an unstated value waiting to be released [10, 11].

The *potential* in Physics acts in a detected force field, it may be positive or negative, it is multiple and not unique, it acts as a function or a flow, and it requires a trigger element to be activated [12].

A critical reading of the existing literature suggests the *Architectural Transformative Potential* as an open function. The *ATP* links the embodied energy untapped in the built matter and the morphological asset related to its structural system.

The paper aims to address the *ATP* as an effective formula to quantify and qualify the amount of potential embedded in the dismissed building stock.

The goal of the research is to evaluate the impact of further use options. The theoretical considerations will lead a cases study selection to test the open formula on real buildings in the future.

2. Material and Methods

The literature review defines the theoretical framework as the post-functional era and identifies the main elements of transformative potential in the field of architecture. The concept is not specified, but it is possible to outline the idea itself as a relation between such main elements. The current research aims at analyzing this kind of potential in its endogenous meaning. Invisible layers related to the space-time dimension are already present in the materials used in the building construction and its stage of obsolescence. Starting from the interpretation of things — human actions in Weber — the speculative structure emerges as a methodological frame capable of measuring the real [7]. The intuition of Yona Friedman [13] seems to find a place in the trends of contemporary architecture, back to the Habraken's *Supports-Infill theory* [14]. By reviewing novel arguments in the contemporary architecture field, such as form and function follow climate and the shape of energy [15, 16], the methodological framework of post-functional theory emerges.

The literature review process underlines the main elements composing the *Architectural Transformative Potential (ATP)*. Primary aspects of the *Architectural Transformative Potential* seem to be the energy embedded in construction materials — embodied energy — and the aptitude to change of the physical space — morpho-structural flexibility.

Acting in the post-functional framework require to proceed by morpho-structural types to assess flexibility. The definition of morpho-structural kinds uses the *Python* calculation system to operate all the possible combinations between the main features composing its shape. The one that is considered either structurally unsustainable or logically not convenient are critically excluded from the set of possible combinations [4, 17].

Embodied energy calculation opens up several methodological approaches, and the database is suitable to change the results as well as thoroughly.

Indeed, the principal methodologies are part of the Life Cycle Assessment to calculate the embodied energy; the process-based LCA and the Input-Output-based LCA. The first one is accounting the values of each step of the building construction, not including the financial system, tracking and quantifying environmental flows, even if it is time-intensive, it is capable of producing building-specific results, allowing the comparison of buildings. The second method uses annual Input-Output models of the US economy, linking monetary values of the building sector to their environmental inputs/outputs [18].

The database of materials in the building sector is necessary for both methods. The first database is the Life Cycle Inventory (LCI) that starts from the 1970' in the United States [19]. According to Stahnel and Reday-Mulvey, the energy issue became relevant in the

framework of circular economy and re-condition processes, in the 1970' [20].

The Embodied Energy became appealing only if inscribed in the framework of an interdisciplinary approach, claiming the fluid essence of architecture studies, interested in redefining the limits of architecture itself [21].

The cases study approach is the methodology to estimate the energy of such materials in existing building, using an existing Life-Cycle Inventory.

The Embodied energy calculation is the further step in the research; the present paper does not measure the amount of energy embedded in each morpho-structural type. The embodied energy discourse concur to select the range of cases studies with the highest amount of embodied energy expected.

3. Results and Discussion

3.1 The Post-Functional System as the ATP Boundary System

The present research aims at contributing to the current debate surrounding the dismissed built environment, adding the concept of *Architectural Transformative Potential*. Contemporary architecture shifts in scale, becoming more and more uncertain and ephemeral. The structure, the frame, the bones are elements that allow the movements and the unexpected to play in-between [14].

The program is still present, not as the unique generative force shaping the project, but as a dynamic mix-use system, changing, expanding and contracting the space, requiring a built frame capable of adaptation.

The form does not follow the function anymore [13]. Nothing has to be designed to support just a unique function in the same space or the same life-span, but this it do not mean that form is dead too. It depends upon how we deal with it. The shape, not considered anymore as a physical, rigid and defined object, is still appealing if defined as geometry embedding a space.

Even if the research focuses on existing buildings, no real theoretical shift occurs. The focus on an existing object does not change what it is irrelevant in an effective way as the previous function. The form is a physical condition but not a generative guideline because the functions are flattering [15].

The climate crisis is a crucial component of this shift, but it is not the only one. The flexibility that our future seems to require plays a significant role, highlighting the energy as a possible generative system for architecture design. According to Rahm, architecture today is free of any formal and functional predetermination;

> "variable, fluctuating, open to meteorological permutations and the passage of time, to seasonal changes, to the alternation of night and day and to the sudden appearance of unanticipated functions and forms" [15].

Architecture may be not function-driven anymore, and the rise of energy-matter as a shaping force could structure architectural space.

Is it possible that such a theoretical approach suits the new buildings only, but the existing ones as well? Maybe the energy already embedded in them — as building construction and a morphology asset — could become a generative power.

The decline of the function-driven paradigm is a severe shift in the evaluation of building stock.

The function regarding dismissed building is not crucial because it is not practised anymore. According to Kahn, a building that has become a ruin is free of the constraints of use [22].

How could it be possible to retrace the energy embedded in the matter, space, the time and the connection flow composing the existing architecture? In this case, this energy is an inactive power; it is its *potential*.

An answer could be to approach the built environment through a structural perspective by its classification. According to Weber:

> "the ideal type represents a conceptual framework which is not historical reality nor the 'true or genuine' reality, though it more or less serves as a scheme by which reality must be subsumed as a template; it

> signifies a pure and limited boundary notion, whereby reality must be measured and compared, to illustrate the significant determining elements of its empiric essence" [7].

Weberian ideal-types underline links and relational connections, being itself a sort of discrete classification. Such methodological framework is not present in the real world, but it shares some features with the real objects, even if it does not derive from them.

The ex-post classification of the built environment allows considering dismissed buildings as infrastructures beyond their previous functional purpose, addressing the concept of *Architectural Transformative Potential* in a scientific way. Such approach intentionally omits a wide range of other subjective values. This omission is essential for underlining a specific kind of potential in architecture — the *Transformative* one — considering the energy embedded in its materials and its shape.

3.2 Elements of Architectural Transformative Potential

The literature of architecture field could highlight an incomplete definition of the comprehensive concept of potential. Starting with Vitruvius, the idea of 'potential' is embodied both in the matter and the function. This concept is touched briefly as an outline between *firmitas* and *utilitas* [23]. According to Rossi, the *potential* shows the fundamental relationship between matter and energy, such a form of dynamic power is the *potential* itself [24]. The *potential* seems a force originated by the incompleteness, linked to ruins and the idea of abandonment [25].

Stemming from the theoretical speculations, another kind of literature linked with the theme *of architectural potential* emerges, one which is more linked to the practice and less conceptual.

Brand focuses on how to prevent the loss of *potential* during the building's life-span, even if he does not define what the *potential* is [26]. According to Douglas, a *building adaptation potential* exists relates to the alternative use and layout of the existing building. The property's location, condition, construction, morphology, and legal restrains will all influence its adaptability [4].

The *Architectural Transformative Potential* depends on both physical condition and further design options. Douglas includes an *adaptation potential* in his to-do-list to analyze the current provision in assessing the building, like the capability to host multiple uses.

Primary elements of the *Architectural Transformative Potential* seem to be the energy embedded in construction materials and the aptitude to change of the physical space. The hypothesis is to outline the concept itself as a relation between such main elements. The current research aims at analyzing this kind of *potential* in its endogenous meaning. Invisible layers related to the space-time dimension are already present in the materials used in the building construction and its stage of obsolescence.

3.3 Morpho-Structural Flexibility Definition

The morpho-structural asset should be addressed as a typological question, even if not in a traditional way. Indeed, the reference to typological studies is related to the interest in finding standard features addressing the options embedded in buildings. Durand provides a matrix of possible types, not embracing the whole but giving an order to the multiple options in design [27]. This simplification of architecture uses a classification process to teach how to design a new building, highlighting standard spatial features beside different functional categories. Durand's method could work as a tool to clarify the state of the existing built environment.

The main contemporary adaptive reuse approaches could be classified as technical and typological [28]. Both methods are valuable points of views, standing upon the functional categories of buildings.

To organize the built environment in structural types — as social *idealtypus* in Weber — both of them seem fundamental to apply an integrated approach. The broad topic requires a goal-oriented lens, such point of

view may be the concept of flexibility.

According to Hertzberger, flexibility suggests an open-ended solution. Such a concept is called the rhetoric value of flexibility by Schneider and Till [29]. Herzberger refers to the term flexibility as being capable of proposing different solutions for diverse users, not proposing a single solution but the most appropriate one [30].

Following the *Support-Infill* theory, it is possible to distinguish the construction components by different life spans and diverse building levels -such as urban tissue, support, infill- or by differences in dealing with fixed or variable components [14].

Brand decodes the multiple layers composing the building: Site, Structure, Skin, Services, Space Plan, Stuff [26]. The layer of the structure is affecting most the essential flexibility, and having the longest life-span, beside the Site. The structure is organizing the space and the fixed features of the building more than the other components. Multiple authors developed many taxonomies, but each of them was referred to as a functional type or to a precise method of building construction [4, 17, 31].

According to Wachsmann, the technological determinism could explain the link between the Gothic cathedral to the industrialized Crystal Palace. Such structural types design analogues spatial assets and somehow a novel classification of the built environment [6].

The morpho-structural broad classification is based on three main classes of parameters, as the central constructive structural systems until 1980'[4], the basic shape of building footprints and the height (Table 1).

The process underlines a high number of possible combinations. This system is a proxy that evaluates a part of the whole building, from a singular point of view (Fig. 1).

Table 1 Morpho-structural classification process.

Height (m)	Plan basic shape	Constructive systems (Douglas, 2006)
A = Skyscraper > 100	a = square	1 = Solid masonry walls
B =Super-high 50-100	b = rectangular	2 = Cavity masonry walls insulated
C = High 20-50	c = round	3 = Framed/panel walls
D =Medium 10-20	d = court	4 = Skeletal frame
E =Low < 10	e = L shape	5 = Portal frame
	f = C shape	6 = Column and plate
	g = triangular	7 = CLASP system
	h = polygonal	8 = “No-fines” concrete
	i = curve	9 = Bunched/bundled tube
	l = free	10 = Slip form wall and slab
		11 = Modular pod
		12 = Tunnel form reinforced concrete

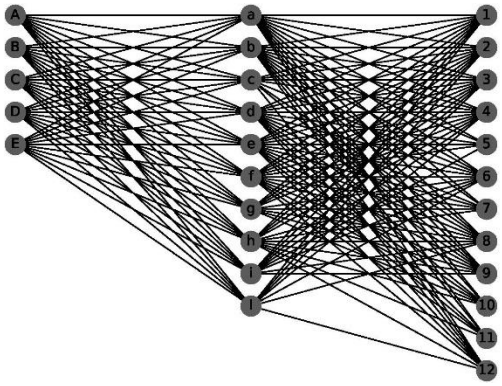

Fig. 1 Morpho-structural possible matches.

3.4 Embodied Energy Considerations in ATP Formula

The embodied energy links the diverse shape of energy embedded both in construction materials and in labour dynamics includes in the built environment. The first definition of embodied energy comes up in the 1970s, being defined as the process of determining the energy required directly and indirectly to allow a system — usually an economic system — to produce a specified good or service [20]. The embodied analysis focuses on how the energy flow affects an economy, placing the role of direct and indirect energy used by a productive system [32].

A comprehensive definition of embodied energy includes the extraction of raw materials, transportation on-site, construction, maintenance, demolition, and disposal stages of the building life cycle [33].

By reviewing the literature, metals and plastics are the materials embedding the higher amount of energy [33]. According to Azari, the type of structural system has an impact on embodied energy. Each structure requires construction materials, a manufacturing process, a way of transport, and a construction system.

The innovative approach is to consider such embodied energy not just in a provisional way, but also in a retroactive way. This *retroactive embodied energy* retraces the history of the dismissed building, its materials and its energy systems. In new buildings, the main contributor in its value is the structure within building layers and the metals within materials. The height seems to be a trigger element for embodied energy [34].

The goal is to assess a range of embodied energy values, linking this result to the morpho-structural asset that already contains multiple design options.

3.4 The Architectural Transformative Potential (ATP) Formula

The *Architectural Transformative Potential* assess the impact of open-options in existing buildings, as just architecture is capable of prefiguring. Such options are qualitative and subjective, and this research does not intend to refute this. However, the approach simplifies the existing architecture realm, underlining a complementary point of view that isolates some features within existing buildings.

The research wants to claim the role of design in evaluating the weight of chances. Possibilities are trigger elements themselves, as having multiple options increases the value, even if just one of them will become real.

The hypothesis is to express it by a function. As shown in Eq. (1) below.

$$\mathrm{ATP} = \mathrm{ATP}_j = x_j + y_j$$

$$\boldsymbol{y_j} = \sum_i^n \mathbf{y_i} \tag{1}$$

Where x_j is the embodied energy measured in j; y_j is the flexibility for each design option j and n are all the possible design options. In the formula, and are expected to be directly proportional one to the other.

The task is to define and convert the member yj in MJ/kg as x_j.

The hypothesis is to approximate such kind of flexibility as the sum of each possible action, even no actions at all, or negative ones.

Following the Research-by-Design approach, such flexibility could be defined through a simplification of design actions, allowed in each building. The previous classification in morpho-structural types allows enlarging the case study general assumptions to its whole category.

The ideal obsolescence condition to have a large amount of open option in reuse practice seems to be the one where the layer of the structure is still present (Fig. 2).

The case study selection will focus on buildings that have a high embodied energy expected, as high-rise ones [34] According to the previous morpho-structural classification (Table 1) these high-rise buildings comprehend different kinds of morpho-structural types, as shown in the scheme below (Fig. 3).

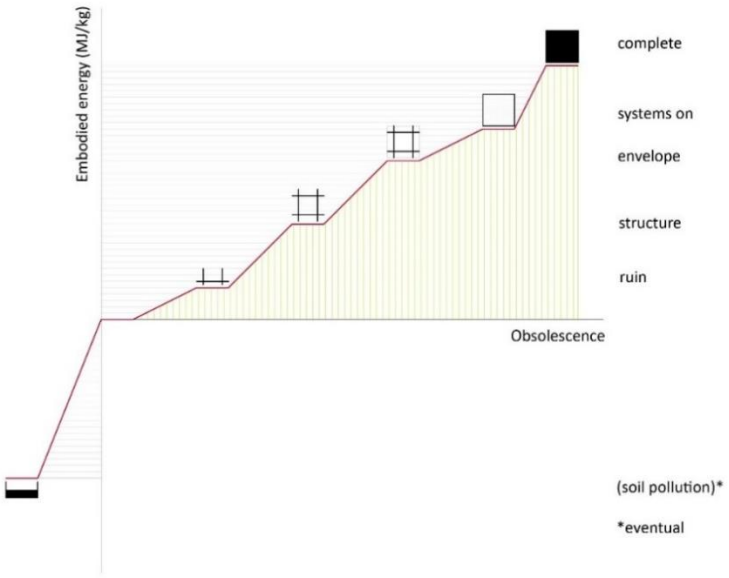

Fig. 2 Structural stages related to the obsolescence.

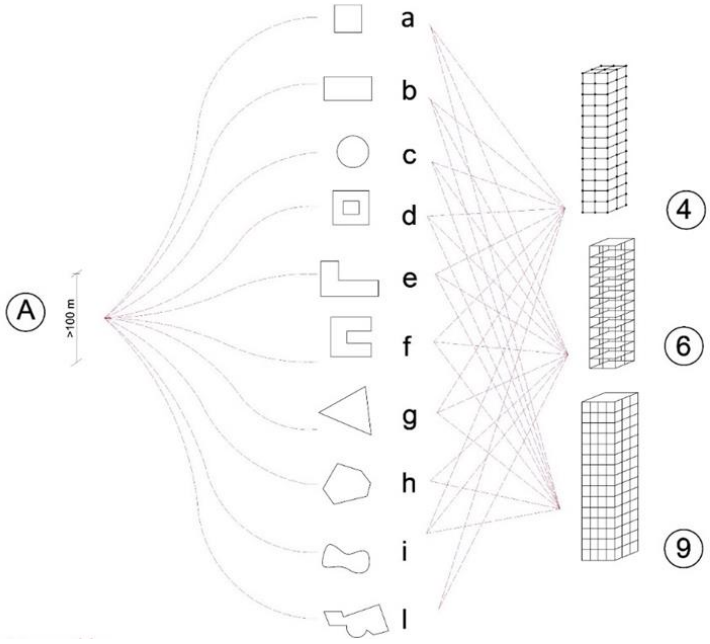

Fig. 3 The 26 basic morpho-structural types (height > 100 m).

4. Conclusion

The present research aims to address the relevance of the concept of *potential* in architecture studies related to the built environment. Such a novel concept is *the Architectural Transformative Potential*. ATP expresses the capability of dismissed buildings to unveil the energy untapped in its matter — *embodied energy* — and the inclination to allow several adaptive design practices — *flexibility*. The energy framework is the reshaping force of the already existing built environment. This framework allows to quantify and qualify the energy still present.

The broader research on the meaning of *potential* underlines some standard features, explaining how it is supposed to behave; it acts in a detected force field, it may be both positive and negative, it needs a trigger

element to be activated, it structures like a function or a flow, it is multiple not unique.

The embodied energy is already defined by a closed formula, even if generally is applied as a predictive tool to design new buildings, instead of an evaluative tool for the existing ones. Quite the opposite happens concerning the morphological flexibility related to structural and constructive systems. Such a concept is expressed in multiple qualitative ways to the existing literature in the field of architecture [17, 18].

The paper introduces a way to evaluate the flexibility in existing buildings. The research will move forward on case studies as existing dismissed building carrying the selected features to test the draft formula of *ATP*.

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