Sustainability from Theory to Practice: An Architectural Analysis of Some Principles of Sustainability in Buildings

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Abstract. According to the Brundtland Report, a sustainable approach should be resource efficient ("development that meets the needs of the present without compromising the ability of future generations to meet their own needs"). How is this definition applied to architecture? And when did it occur? Strange as it may seem, the preoccupations for a sustainable environment did not appear in the past decades. It is as old as the building process itself: vernacular architecture can be interpreted as a process of building, taking into account the impact of the rules of nature on the environment; religious, monumental, civil or industrial architecture might have components that provide sustainability, if they meet some specific conditions. The paper aims to present some considerations of the architectural evolution of the concept of “sustainability”.

1. Introduction

For over three decades the noun” sustainability” has been subject to interpretations, comparisons, clarifications and research. The famous Brundtland Report of 1987 offers a broad definition that is applicable to all fields of human activity affects and interacts with the environment. Sustainable development is the development that meets “the needs of the present without compromising the ability of future generations to meet their own needs” [1]. Less quoted but just as strong, the next statements of the Report provide the directions of action: “It contains within it two key concepts:

• the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
• the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs”.

In time, the meanings of the term were discussed and broadened and today The 2030 Agenda for Sustainable Development [2] emphasized 17 goals to transform our world into a sustainable one. Grouped in categories they would determine changes in the society (No Poverty, Zero Hunger, Good Health and Well-being, Quality Education, Gender Equality, Reduced Inequality, Peace and Justice Strong Institutions, Partnerships to achieve the Goal), environment (Clean Water and Sanitation, Affordable and Clean Energy, Responsible Consumption and Production, Climate Action, Life Below Water, Life on Land) economy (Decent Work and Economic Growth, Industry, Innovation and Infrastructure). All these 16 goals are performed inside and by communities / cities, that must also be sustainable, which implies accomplishing the goal of Sustainable Cities and Communities.
From the three Pillars of Sustainability defined by Barbier in 1987 [3] as the social system, the biological and resource system and the economic system, the management consultant John Elkington defined in the early ‘90s the “triple bottom line” People - Planet – Profit [4]. Today we are dealing with (more or less) five “P’s: People, Planet, Prosperity, Peace and Partnership [5]. From the 1987 definition to today’s goals of no poverty and zero hunger, the “Profit” pillar aiming in fact the economic impact on society, therefore “Prosperity” is considered more accurate and the two goals of Peace and Partnership have the strength and determination to stand as independent pillars.

For communities (villages, towns, cities), targets were set for 2020 (and we are there already) and aimed to “substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels”[6]. For the next decade, the aim is to provide for everybody access to “adequate, safe and affordable housing”, sustainable transport systems, to reduce the number of deaths and the number of people affected of natural or anthropic disasters (including waste management, bad air or water quality) and to increase the “green and public spaces”, especially for the sensitive categories of persons (elderly, children, women and disabled).

Absolutely all human activities deal with buildings, directly or indirectly: from birth to death and from dwelling to work place and from production to storage, everything has to do with buildings, therefore the focus of this paper on buildings and on the influence, connections and impact of the built environment on the environment, society and economy, is major. No wonder that the building construction accounts - according to the official figures of the 2017 United Nations Global Status Report “Towards a zero-emission efficient and resilient buildings and construction sector”, [7] - for around 36% of total final energy use (including the manufacturing of materials for building such as steel and cement), 28% of global energy-related CO\textsubscript{2} emissions, with direct emissions in buildings from fossil fuel combustion. Buildings construction represented another 11% of energy sector CO\textsubscript{2} emissions.

2. Principles of sustainability in building practice

Sustainable buildings should provide a balance between the use of natural and energy resources, the generated by-products and waste, while ensuring safety, comfort and health for the occupants. Preoccupations in the building sector and in cooperation with research in different industrial fields tend to increase the role of the building as a large-scale battery, by using alternative energy resources, thus covering the needs of the building and achieving the extra energy for other sectors. In this context, the use of the sun – through both passive and active approaches – of the air movement, of hydropower, biomass, geothermal and cogeneration are all means (not targets!) for alternative energy resources and must be considered for integration within building products, from as early as the design phase.

The use of local materials is emphasized, as transportation of the materials and products implies use of energy and produces pollution. Furthermore, at the European level, the necessity to recuperate, reuse, recycle is, in fact, a must, as the Regulation (EU) No 305/2011 [8] specifically states in Annex I, the necessity of the “reuse or recyclability of the construction works, their materials and parts after demolition” as a basic requirement for an economically reasonable working life, for construction works.

Local labour-hand is also encouraged as it is related at an individual scale with transport (as stated above) and, as at a larger scale it produces massive human migrations that break the balance of the
existing settlements either by overpopulating the existing localities or by abandoning settlements, thus leading to social, economic and environmental problems.

The building cannot be considered without the connections to and with the surrounding environment, as it affects the existing natural and built landscape, from the shadows it casts on the existing site to the waste and water management, temperature rise or pollution. At a larger scale, urban agglomerations – consisting of conglomerates of buildings connected with streams of traffic and urban facilities – multiply heat, noise, waste, pollution and other aggressive effects at the city scale.

As mentioned before, the accent should not be set on the energy efficiency but on the building where energy is just one issue that is managed wisely. In other words, the building should not loose the characteristics that define it since the Antiquity: Firmitas (Durability) – Utilitas (Convenience) – Venustas (Beauty)[9] or, in the words of Vitruvius, “All these must be built with due reference to durability, convenience, and beauty. Durability will be assured when foundations are carried down to the solid ground and materials wisely and liberally selected; convenience, when the arrangement of the apartments is faultless and presents no hindrance to use, and when each class of building is assigned to its suitable and appropriate exposure; and beauty, when the appearance of the work is pleasing and in good taste, and when its members are in due proportion according to correct principles of symmetry.” [10].

Today the concerns seem to be on how the buildings can provide more energy and less on the comfort and the well-being of the occupants, although the focus should be placed on the quality of the interior space1 and where natural light, indoor (and outdoor) air quality, water and waste management are subject to quantifiable performances; the state of well-being derives from proportions, colours, space in general and it is not subject to a formula or a prescription (although it is true that proportion is what Vitruvius was mentioning over 2000 years ago).

3. Sustainability in the building history

Vitruvius was the first theoretician of architecture that we know of: although names of architects before him are known to us, it is this Roman soldier and engineer the one to whom we owe the first book (in fact, there are ten of them), of architecture as a theoretical and scientific field. Furthermore, the principles stated by Vitruvius are still valid today: “Architecture is an imitation of nature, as birds and the bees built their nests so humans constructed housing from natural materials that gave them shelter against the elements”. In other words, the precise core of the theory of biomimetic architecture. What we know today as bio-climatic architecture can be tracked back to the same ancient author who was explaining how to choose a healthy site (that should protected against winds, heat and moisture) “since healthfulness is, as we have said, the first requisite” [10].

It is highly probable that Vitruvius in fact collected information from wherever he travelled, as a military, in Augustus’s army, but nevertheless his contribution to the theory of architecture is fundamental and priceless, as fundamentals are the principles that he presents, in use to this day. In a different society, based on oral transmission of information, the same principles have been in force: in the world of the vernacular, where “eternity was born in the village”2. In any village.

3.1. Perennial functions, replaceable materials

Everywhere on planet Earth, the same architectural features can be identified when the same natural agents occur, the same geology and climate, the same materials, (Figure 1). Architecture, in the

1 Zaha Hadid: “Architecture is really about well-being. I think that people want to feel good in a space… On the one hand it’s about shelter, but it’s also about pleasure.”

2 Lucian Blaga, a Romanian poet, philosopher and novelist, wrote “I believe that eternity was born in the village / Here, any thought is slower”
Vitruvian meaning as a triade of durability, functionality and beauty, gives a familiar feeling as it is shaped with the local materials and taking into account the local climate and the human scale (not with aesthetic significance but, as the dwellings are tailored according to the occupants, to provide maximum efficiency with minimum expenses).

![Image]

**Figure 1.** Traditional architecture in Poland (left) and Romania (right)
Photos: left - Albert Jankovski, right: Ana-Maria Dabija

In these cases, aesthetics is usually accomplished at the scale of the details: wooden carvings, for example, of the window jambs, beams or columns personalize and grant unicity for each dwelling (Figure 2).

![Image]

**Figure 2.** Wooden carvings in an underground hovel, Romania. The head of the left beam is shaped as a horse head. Photo: Ana-Maria Dabija

It is obvious that these dwellings, ageless in terms of style and building techniques, have been subject of interventions: elements have been replaced or repaired, in most cases with the same materials or and technologies. However, this is not always the case as, should local industry for specific building elements develop in the area and should the locals know the characteristics of the new product (they might have worked in the factory or installed such products), some components like the roof wooden shingles might be replaced with corrugated fiber cement or metal panels, providing a longer service-life (Figure 3).
Figure 3. A village in Maramureș, Romania: traditional houses with roofs of wooden shingles and houses with roofs that were replaced with corrugated fiber cement panels. Photo: Ana-Maria Dabija

While in most cases the replacement of some elements is carried out when they begin to fail (they rot, break and so on) there is one case (that we know of) where replacement was considered from the stage of the design, over 1500 years ago and has been carried out despite wars, tragedies or disasters. It is the complex of the Great Shrine of Ise, in Japan (Figure 4).

Built around the 7-th Century CE for Amaterasu, the complex counts 125 buildings and represents the most sacred religious place of Japan. The unicity of the assembly is that the two most sacred shrines – of Amaterasu, goddess of the sun and light and of Toyouke, the food goddess – as well as other 14 buildings including the Uju bridge and Torii gateway, are rebuilt every 20 years; 48 of the other constructions of the assembly are also rebuilt every 40 years [11] The most recent reiteration of the shrines was in 2013.

The project, the technology and the building materials are the same as in the original building: 200 years old cypress wood. The completion of the new buildings takes about 8 years after which the old shrine is disassembled and the pieces are sent to other Japanese shrines [12].

The idea of periodical rebuilding was considered within the original concept and therefore there are “twin sites”: the one with the functioning shrines and the one with the buildings in construction. Needless to say that the act of building itself is performed according to a religious ritual (Shikinen Sengu) and, in the end, both shrines are side-by-side; the new one is consecrated and it begins its ritual life while the old(er) one is disassembled. In the passing 20 years between the iterations, the know-how is managed and transmitted from one generation to the next, without distortion. It was a solution of preservation of the building techniques in a world of workers that, presumably, was not educated in professional schools.

There may be two motivations behind this act of building and dismantling. One may be the philosophical and religious explanation: Amaterasu maintains harmony and order and provides the necessary nourishment to the living souls; she rules the path of the day towards the night and each new morning is a new beginning. Toyouke, as the goddess of agriculture, represents the periodical rebirth of nature. Each reiteration of the shrines marks a new beginning or an energetic reload of the sacred
places. The other, more prosaic motivation is that in Japan, a country with major seismic hazard, it seemed more efficient to rebuild instead of repair a structure that was affected by an earthquake.

Whatever the reason, behind the story of the permanent building of the Grand Shrine, one may discover contemporary principles of sustainability in building: integration with nature, local materials and techniques, dismantling instead of demolition, circular economy (recuperate, recover, reuse), know-how correctly transmitted to the next generation of workers.

![Figure 4. Images from the Great Shrine in Ise complex. Left: the Uji bridge, right: the access to the gate of the Toyo’ukedaijingu (Geku) shrine. No visitors are allowed inside the courtyard, but one may peep to see the state-of-the-art of the construction. Photo: Ana-Maria Dabija](image)

3.2. Perennial materials, replaceable functions.
Durability and sustainability are not the same but, in the case of the Grand Shrine, it is difficult to say: wood is not durable; neither is the reed, required for the thatched roofs. Nobody can decide if the Grand Shrine is old or new and if by rebuilding it, an act of culture is performed or an act of destruction of an architectural monument. It is our opinion that the substance of a monument consists of both, the material and the immaterial dimension and by splitting them, the balance is lost. Maybe this can act as an explanation for the decision taken by authorities for reconstructing several buildings that fell after catastrophes (wars, quakes or absurd demolitions): the Opera in Vienna, the Campanile di San Marco in Venice, the cloister of Santa Chiara in Napoli and many other examples.

On the other hand, there is a massive stock of buildings that have lost their original architectural functions. Mostly it is the case of nobility or royal residences that entered into national patrimonies, industrial sites and buildings that have been abandoned (due to death of the industry or the change of technology) and in some cases religious buildings that have been abandoned (a common practice in some of the Northern European countries). An abandoned building decays faster than an occupied one.

It is accepted that, 30 years from now, (at least) 70% of the existing stock of buildings will still exist. In other words, we have to deal with many of the existing constructions and to adapt, re-functionalize, convert them to the contemporary needs.

It is, thus, a sustainable approach to analyse what to transform a solid, brick or stone building, into.

Converting palaces to museums is not something new; in the case of religious buildings, there were two situations: one by force, in order to kneel the population after a (political or religious) conquest and another more pacifist approach, in the past decades, where abandoned churches were converted (Figure 5) to almost any imaginable function, from market to library and from hotel to offices, thus conferring a new life-cycle to an existing structure.
Another well known example is the transformation of the Orsay railway station, designed by Victor Laloux, Lucien Magne and Émile Bénard and built in 1900 (Figure 6, left) into the famous Musée d’Orsay (Figure 6, right), that opened its gates in 1986.

The new life of this building is granted by a politician, Jacques Duhamel who, in 1973 rejected the idea of demolishing the old and outdated Gare d’Orsay and building a new hotel in its place [13]. ACT Architecture redesigned the interior, by providing extra floor surfaces and architect Gae Aulenti is responsible for the interior design.

In all the situations of conversion, the design process is a challenge as it requires fitting the new functions in the existing space, with the appropriate changes and interventions that accommodate the contemporary building services and equipment. Dismantling or demolishing is necessary in some spaces, constructing new structures or consolidating the existing ones is also sometimes necessary.

Conversions may be carried out on parts of buildings, for example transforming lofts into spaces with architectural function. Such interventions offer the designer the possibility of integrating passive or active systems to diminish the use of energy from traditional sources (Figure 7).
Figure 7. The transformation of a 100 year old loft (left) into an office level, at the Ion Mincu University of Architecture, in Bucharest. Daylight is granted by sun-tunnels. Artificial light is provided from batteries that store electricity produced by BIPV placed on the Southern slope of the building. Photos: Ana-Maria Dabija

3.3. Perennial functions and materials

A specific case is represented by the process of rehabilitation of the mass residential buildings, with the declared target of improving their energy performance. In this case, updating the stock of existing collective / mass dwellings doesn’t involve changes in the spatial configuration but usually involves updating or installing new HVAC systems. In some cases, this action requires finding spaces for technical purposes but in most situation the existing routes are sufficient. Major interventions are carried out on the envelope, as it is the system that separates the environments with different hygro-thermal characteristics.

Wrapping the building in a warm blanket is the easy – and in most cases the cheapest - approach but it also represents a time bomb in terms of… sustainability: poor detailing, cheap materials and low or un-qualified labour force may induce pathologies that the outdated buildings did not have, prior to the interventions [14]. If the “blanket” represented by a common thermal insulated product (of expanded polystyrene or mineral wool) is laid over a 60-year-old thick plaster or cladding, destroying it, obviously and the new finishing layer is a 5-6 mm thick plaster layer (Figure 8), the question that comes forward is which of the two systems was, in fact, sustainable: the one that resisted 60 - 70 years or the one that needs maintenance every 5 years? It is not the system that we doubt but the field of application and the incomplete “script” and detailing that is in the responsibility of the designer.

Figure 8. Thick plaster and ceramic cladding of the 80s (left) and thin plaster layer on polystyrene after a year of use (right). Photos: Ana-Maria Dabija
3.4. Back to square one: lessons from the vernacular
The traditional architecture is the inspiration of several architectural trends and styles of today: eco-architecture or bioclimatic architecture have the roots in the vernacular principles; biomimetic architecture follows principles of organic constructions or that are carried out by the humble creatures: termites, bees, beavers [15]. Solar architecture is over two millenniums old and humans have heated the water for domestic purposes since the Antiquity. What we call today “green roofs” were hanging gardens in the ancient Babylon and were a common roof building system in the Viking era [16]. Descending to the scale of the building components, the principles of cross ventilation deal with opening windows and the stack effect is related to the trivial chimneys of the buildings in the temperate or cold climate as well as to the wind towers of the Middle East; shading devices placed on the Equator oriented facades have always been dimensioned to provide maximum efficiency while ensuring the constant inner temperature; double windows are not a contemporary invention: in cold climate they were used long before the energy crisis [17]. Radiant heating of the walls and floors can be tracked back to the Antiquity [18, 19]. And such examples can go on.

4. Conclusions
In architecture, the field of sustainable design is neither easy nor possible to define with a mathematical rigour. There are some certainties that architects keep in mind:

- there is a similarity between buildings and living creatures: they can be healthy, they breathe, they get sick (sick building syndrome), they develop pathologies (building pathology), they die. Sometimes buildings give the impression that they are happy or agonizing. Therefore, maybe Hippocrates’ “Primum non nocere” 3 should apply to buildings as well. An ill building will make the inhabitants ill as well;

- interventions on an existing building are complicated, even if the building is, allegedly, a mass building with no cultural value: it is never identical with the project and almost each assembly should be detailed individually, after an appropriate measured drawing. This never happens in the thermal rehabilitation approaches. Furthermore, there is a risk that the new interventions might change the interior microclimate parameters ant thus induce a pathology that the building did not have, prior to the intervention;

- remember the lessons of history and the lessons of nature; building with the nature and like nature is always providing correct solutions

- a sustainable building is not an assembly of materials, technologies and systems; it requires an architectural idea and a concept that fulfils the Vitruvian triade: firmitas – utilitas – venustas.

The rest is… not silence, but Corbusier’s “masterly, correct and magnificent game of the volumes brought together under the light”

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