Buildings and Environment: Evolution or Adaptation?

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ABSTRACT: Following the discovery that emissions resulting from human activity are contributing to the global warming of the planet and to consequential major climate changes, the paper investigates how we can maintain our quality of life without destroying the very system that supports our existence. The knowledge gaps which exist with respect to how built structures can evolve - adapting to climate changes - must be filled, impacting on form and fabric of buildings in order to ensure their continued liveability. The paper attempts to integrate the notions of adaptation as seen in natural evolution - where the capacity to survive depends on the ability to adapt to a changing environment - with the concept of environmental responsibility. Evolution and adaptation are fundamental to life and are strictly bound to an ecological and sustainable design process; an “adaptive” attitude in the way in which we conceive our built environments provides then a conceptual basis for the advanced building design of our future, as well as one concerned about the efficient management of natural resources, playing a priority role in the collective efforts required to avoid a possible significant environmental degradation, while improving physical, physiological, and psychological human comfort and well-being into built inhabited spaces.

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INTRODUCTION

The last 12,000 years have been a period of relatively stable climate [1]. Obviously, there have always been slight variations in local weather, but usually changes took place so slowly that living beings did not notice it; animals, plants and other forms of life have had time to adapt or migrate.

However, since the Industrial Revolution began, everything seems to be speeding up: apart from what has been done to the land, humans have been changing the chemistry of the atmosphere through combustion of fossil fuels and living matter, bringing about the prospect of global changes and alterations in whole weather systems. Although some scientific uncertainties remain, we now seem set on a course of human-induced global climate change dominated by the potential and impending risk posed by the greenhouse effect (fig. 1).

Figure 1: The greenhouse effect

We all are already familiar with the threat of global warming brought about by the build-up of heat-trapping gases (such as carbon dioxide) in the atmosphere due to human activities. Most models predict more severe weather: hotter hots, cooler colds, shifts in seasons, and a chain of other climatic events. Such changes could cause rain to fall where it rarely fell before, or rain not to fall where it had previously been abundant. It may be warmer or it may be cooler, although the world as a whole seems set for a rise in average temperatures.

A warmer atmosphere draws more water from oceans, resulting - as global thermal contrasts grow more extreme - in bigger, wetter, more frequent storms, droughts, hurricanes and rises in sea level, that could, for example, totally disrupt the lives of the populations living on (or near) a coastline, or along an estuary. There are also concerns about the damage being inflicted on fragile ecosystems by increasing development and resource extraction, and about the depletion of the ozone layer, which allows harmful ultraviolet radiation to penetrate the lower atmosphere.

In parallel with these often imperceptible effects, there has been a general deterioration in air quality, most striking in urban areas. Incinerating fossil fuels contributes particulates to the environment, where they are known to cause respiratory and other health problems. Last, there are the issues arising from the destruction of some forms of life caused by changes in patterns of disease. Temperature and moisture greatly affect the life cycles of micro-organisms - from insects through bacteria to viruses - which, therefore, directly affect human and other animal health.

Facing this potentially catastrophic degradation, it may be a shocking revelation - especially to an architect - that this environmental crisis is basically
driven by mankind's habitat: the buildings, the major destroyers of the ecosystem and the greatest threat to humankind's survival on the planet!

Actually, it is in built environments where we can find an amazing accumulation and combination of hazards, each driven to a greater or lesser degree by human population increase and urban growth. In the evolution of human behaviour from hunters to farmers and eventually citizens, inhabited environments have brought all dangers together in acute form; when the archaeologist of the future will look at the deposit of the last two centuries, they will probably find a biological discontinuity as big as any in the past, exposing a richness not of fossils but of plastic bags and other human refuse [1].

Taking awareness of this global situation and the inevitable continued growth of built agglomerations, an approach based on the design of cities and buildings living per se is going to lead to civilisation's self-destruction. Arts of architecture and city planning should then evolve to provide crucial tools for safeguarding our future, creating constructions that provide sustainable and civilising environments as the springboard for restoring humanity's harmony with nature.

2. EVOLUTION OR ADAPTATION?

2.1 The need for sustainable built environments

Built environments are centres of communication, learning and complex commercial enterprises; they house huge concentrations of families, focusing and condensing physical, intellectual and creative energy. Cities are places of hugely diversified activities and functions, with a great combination of ages, races, cultures; a mix of community and anonymity, familiarity and surprise, dangerous excitement. Nevertheless, the first and most obvious thing about built environments is that they are like engines, sucking in resources and emitting wastes; the larger and more complex they become, the greater their dependence on surrounding areas, and the greater their vulnerability to changes around them.

As a matter of fact, rather than being designed around a natural and cultural landscape, most modern urban areas have simply grown like cancers, spreading more and more of themselves, eradicating the living environment in the process, and blanketing the natural landscape with artificial layers of concrete. Paradoxically, cities have grown and changed into their vulnerability to changes around them.

In order to respond to the needs imposed by a sustainable development of human activities and environments, a new form of design must then be progressed, able to fully respond to the requirements of modern living. New concepts of building and urban planning that integrate social responsibilities are requested, making our approaches to built environments evolving through the adaptation to specific needs, wishes and conditions. The key probably lies in cities aiming at a circular “metabolism”, where consumption is reduced by implementing efficiencies and where re-use of resources is maximised. We must recycle materials, reduce waste, conserve exhaustible energies and tap into renewable ones.

However, since the large majority of production and consumption takes place in cities, current linear processes that create pollution from production must be replaced by those that aim at a circular system of use and re-use; these processes could increase city's overall efficiency and reduce its impact on the environment. To achieve this, we must plan our built structures to manage their use of resources, developing a new form of comprehensive holistic and “adaptive” architectural design, able to increase energy efficiency, respond to the climate changes we are facing at the moment, consume fewer resources and produce less pollution.

In this scenario, buildings designed as if they were stand-alone objects, rather than elements that enclose and shape the public realm, would still act as parasites on the landscape; huge entities draining the world for their sustenance and energy. For this reason, as well as framing public life, buildings should act as “environmental filters” that enhance exchanges between internal and external environments, activating consequently differentiated strategies to “adapt” to variable conditions, climates and functions, and thus minimising their energy demand. On the other hand - even from a conceptual point of view - we do live in a world that is dynamic and constantly evolving, so it is fundamental for us, and for the built environments that surround us, to take part, or at least be aware, of these changes.

This raises the practical question of how to make building design evolve in order to keep pace with people's requirements and to alterations in the climate. In this logic, buildings that are adaptive and, hence, easy to modify may obviously have a longer useful life and represent a more efficient use of resources; however, designing flexibility of use into our buildings will inevitably move architecture away from fixed and perfect forms, with a consequent dramatic impact on our traditional aesthetic conceptions, expression of the architect's creativity.

Classical architecture, for example, has derived its beauty from its harmonious composition: nothing can be added to it, nothing taken away. But when society and climate are demanding buildings capable of responding to changing requirements, we must provide flexibility and search for new forms that express beauty within adaptability.

What is brought into question here is one of the main postulates of the historical western culture: the conception of the aesthetic object structured as a
moment of opposition - a “perennial monument” (*aere perrenis*), the Latin poet Oratus would say - against the temporariness of existence.

No more matter to be perceived just by the sense of sight, that has the tendency to freeze the complexity of reality in abstract and lifeless images - the absolute eye-centred Renaissance perspective (fig. 2) - but rather an organism founded upon the involvement of the whole of the senses, that work together and that, in their turn, determine further transformations and the opening of new significances.

**Figure 2: The ideal city by Piero della Francesca**

As a consequence, buildings will become complex nervous systems, sensible entities to interact with, “objects” that may adapt to our ways of inhabiting spaces; vibrant and harmonious “creatures” able to change according to the user needs and to the dynamics of environmental forces.

New needs require new forms. However, before getting on with this issue, it is important to stress out another essential concept: when we talk about the need of an evolved approach to building design, the aim of the task is about more than “just” saving important energetic and natural perishable resources. Architecture always expresses a point of view, a perspective, but it also must involve an ethical way of behaving in relation to the environment. For this reason, more than ecological design, we have been talking about sustainable design, where the term “sustainable” is intended to add also the dimension of time. A sustainable development implies, hence, an ecological approach that includes also a great responsibility to the future, according to its definition as to “keep in existence, prolong and maintain”.

As we get to this point, other questions arise: aesthetics, beauty, health, well-being and quality of life can be said to be as important as an environmental approach as are energy intake and resource depletion, since a building cannot be considered to be really “sustainable” if it is not also a pleasant place to live and work in.

“Sustainability” is, thus, assuming a wider sense; not just reduction of consumptions, wastes and emissions, but rather “appropriateness” to the use, and thus flexibility, adaptability, maintainability, and finally, actual constructability of the building. Inflexible buildings hamper the evolution of society, while buildings that are adaptive and, hence, easy to modify may have a longer useful life and represent a more efficient use of resources.

2.2 Eco-effectiveness of adaptation

Let’s just simply imagine the primordial beginning of life on this planet. There is rock and water - matter; the sun sends out heat and light - energy. Eventually, over thousands of millennia, through chemical and physical processes, single-celled bacteria emerge; a monumental change takes place. Chemistry and physics combine with the sun’s physical energy, and the Earth’s chemical mass turn into the blue-green planet we know. Biological systems evolve to feed on energy from the sun, making the planet’s surface explode with life forms, a web of diverse organisms, plants, and animals [2].

Amongst other successful animals, the human species, during his millenary evolution, learned through constant trial and error to adapt to many different environments. Nevertheless, unlike others, humans make a jump from being successful to being a runaway success, learning how to adapt environments for their own use, in ways that no other animal can match. Actually, humans have been the only species that has taken from the soil vast quantities of nutrients needed for biological processes but has rarely put them back in a usable form.

The design response of humans to the evolution and diversity of life might thus be called a de-evolution, i.e. a simplification on a mass scale. Layers of concrete and asphalt have obliterated forests, deserts, costal marshes, jungles; bland, monotonous and uniform buildings have spread and spread, overwhelming the details of place in their path.

The survival of societies (vegetal, animal, etc.) has always depended on safeguarding the equilibrium between the variables of population, resources and environment; neglecting this principle has had disastrous consequences for civilisations of the past. We too are subject to the controlling laws of survival, but, unlike our predecessors, we are the first to be a global civilisation and, therefore, the first to have ever faced a simultaneous and world-wide expansion of population, depletion of natural resources and erosion of the environment.

Given the previously mentioned scientific uncertainty concerning the precise long-term effects of current levels of consumption and emissions of wastes in the environment, we’d probably better ensure the action be taken to safeguard the survival of our species on this planet. Therefore, if humans are truly going to prosper, we have to re-learn how to imitate nature’s highly effective system of nutrient flow and metabolism, in which the very concept of waste does not exist.

The idea of our buildings evolving through adaptation, hence, may be considered as an attempt to integrate the notions of responsiveness to the environment (as seen in natural evolution), with the idea of environmental responsibility: the striving for optimal performance and increased comfort, all with the minimum consumption of energy. This is partly related to ‘passive’ notions of adaptation, and partly to the efficiency of their metabolism. It is possible to imagine living creatures, for example, which survive and adapt to an hostile environment, but which have to work so hard (in terms of their circulatory system) that their life would be short and precarious: such a species would soon die out [3].

On the other hand, proposing the application and the integration in architecture of an adaptive and ‘responsive’ behaviour, able to react to external climatic variations and to variable needs of users in order to improve building energy performance and
internal comfort, simply extends ideas and principles consistent with the proposition of Darwin, who held that the capacity to endure depends on the ability to adapt to a changing environment.

The animal and vegetal world teaches us that the species which survive over evolutionary time scales are those who live in the environment of the planet with the least effort, i.e. the least expenditure of energy to maintain life; perfectly adapted creatures, existing as a result of evolution, shaped and constructed in such a way as to minimize the effort required to run metabolism. Food and waste balance each other, while the necessary energy is provided by the sun. According with the alternating seasons, for example, the animal coat moult, trees lose leaves, seasons and behaviour correspond.

This biological metaphor may seem unnecessary, but the idea of economy of means lies at the root of many aspects of design; this is how living beings have evolved, and there are good reasons for us to want buildings to evolve in the same way (fig. 3).

Figure 3 – The polar bear: evolution and adaptation

This theme provides a conceptual - and perhaps aesthetic - basis for the buildings of our future, as well as one founded on efficient resource management and concern about climate changes and global warming. Evolution, however, is not so much concerned with the survival of the fittest, strongest, leanest, largest, perhaps meanest, but rather with the non-survival of the unfit. Built environments, with their increasing need for the importing of energy, have been evolving so far in a rather unsustainable direction: as a consequence, more advanced forms of building ‘life’ are essential if an expanding world is to provide itself with comfortable buildings, with an equitable spread of technology and quality of provision.

The vitality of ecosystems depends on relationships: what goes on between species, their use and exchanges of materials and energy in a given place. Nevertheless, taking on this approach, does not simply mean to build in a more eco-efficient way, as it has often been said.

The term “eco-efficiency”, in fact, implies an approach that has a very fixed vocabulary: reduce, avoid, minimize, sustain, limit, halt. Whether it is a matter of cutting the amount of toxic waste created or emitted, the quantity of raw materials used, or the product size itself, reduction is a central tenet of eco-efficiency. But reduction in any of these areas does not halt depletion and destruction at all; it only slows them down, allowing them to take place in smaller increments over a longer period of time [2].

Certainly, eco-efficiency is to be considered as an outwardly admirable, even noble, concept, but it is not a strategy for success over the long term, since it does not reach deep enough. Working within the same system that caused the problem in the first place, but merely slowing it down with proscriptions and punitive measures, it thus presents little more than an illusion of change. Relying on eco-efficiency to save the environment will eventually achieve the opposite; it will let industry finish off everything, quietly, persistently, and completely.

Moreover - last, but not least - efficiency isn’t much fun. In a world dominated by efficiency, each development would serve only narrow and practical purposes, while beauty, creativity, fantasy, enjoyment, inspiration, and poetry would fall by the wayside.

Logically, this is not to condemn all efficiency; when implemented as a tool within a larger, effective system that intends overall positive effects on wide range of issues - not simply economic ones – efficiency can actually be valuable, as it is valuable too when conceived as a transitional strategy to help current systems slow down and turn around. But as long as human activity is so destructive, attempting only to slacken its pace is a fatally limited ambition; if the goal is zero - zero waste, zero emissions, zero “ecological footprint” - we turn out to a depressing vision of our species’ role in the world.

For this reason, in order to evolve through adaptation, we should rather talk about an eco-effective approach, one that instead of being simply energy-efficient may foster a side effect of a broader and more complex design goal: to create buildings that celebrates a range of cultural and natural pleasures (sun, light, air, nature: the dynamic of environmental forces), able to enhance the lives of the people who inhabits them - with economic as well as aesthetic consequences - and to meet the whole of the physical, physiological, and psychological human needs, but always in a strict connection with the environment that houses and “sustains” our very existence.

3. SUSTAINABLE ADAPTIVE TECHNOLOGY

3.1 An “archi-technological” approach

Technology and our ability to predict have transformed our world. The speed of technological change and, above all, the wideness of its dissemination provide modern society with its greatest potential power.

Robotics, education, medicine, global communication - all manifestations of our technological development - provide the conditions for the growth of a new form of creative built environments (at the scale of the building as at the scale of the urban agglomeration) that could generate wealth for society, without breaching the limits of our environment’s sustainability.

The challenge we face is to move from a system that exploits technological development for pure profit to one that has sustainable objectives. In any case, making our activities sustainable demands a fundamental change in human behaviour, with a
particular focus on the practice of government, commerce, architecture and urban planning.

Architecture actually emerged from mankind’s need for shelter; it soon became a fundamental expression of technological skills and of spiritual and social objectives. The history of architecture documents humanity’s ingenuity, its sense of harmony and values; it is a profound reflection on the complex motives of individuals and societies. Architecture extracts beauty from the application of rational thinking. Architecture is the play between knowledge and intuition, logic and spirit, the measurable and the immeasurable.

Nevertheless, today the rich complexity of human motivation that generated architecture in its first instance is being stripped bare; building is pursued almost exclusively for profit, that determines the form, the quality and the performances of built spaces. However, if buildings are designed for people and not only for aesthetic or profit reasons, they must always provide the right environment for the well-being of the occupants and their activities; the value of a building, in fact, relies not only upon its rentable net area but also upon the quality of the space it envelopes.

Technology, hence, must be focused by the human for the benefit of the human; it should seek to protect universal human rights and mobilise creative thinking to secure humanity’s future on this small planet of finite resources. The question, then, becomes how to use technology, at what scale, and for what purposes. At one extreme, in fact, one may argue that an increased use of advanced technologies in architecture could turn it away from the environment, ecological awareness, and perhaps even from a sustainable future; on the other hand, if appropriately used, it is actually possible that technology could move us forward in an ecologically responsive way.

Indeed, solutions with technological and architectural integrity can be found only if the benefits and limitations of technology are carefully weighted with other architectural strategies. We should always consider, anyway, that technology is not the absolute answer, although it is a fundamental means. Therefore, it is in general always necessary to be aware of the union between what we have available as natural resources and what we may then control with technological features, so as to obtain the best gain concerning energy consumption, contribution to the user’s satisfaction, well-being and good performance of human activities [4].

What a sustainable approach should provide is, thus, building morphologies which, both by the shaping of the form and the application of technology, can reduce the need for importing energy for heating, cooling, lighting or ventilation. Sustainable design means striving to have our buildings in harmony with nature, dynamically connecting to natural flows in order to rethink our approach to creating and inhabiting built structures. It means merging ancient and new technologies for re-establishing our fundamental connection to the sources of all good growth on the planet: sun, wind, water.

For decades, we have been designing buildings like machines; but this time, instead of a "machine for living in" we should evolve our building techniques and try to design an adaptive machine that’s alive.

In place of built environments that overwhelm the environment and alienate our communities, we must build settlements that nurture both. Buildings should inspire and compose cities that celebrate society and respect nature. Our present need for sustainable building now offers opportunities to re-establish ambition and to evolve new aesthetic orders.

Flexible, adaptive, responsive and dynamically changing buildings offer us new ways of organising our lives; these concepts encourage a vibrant society and reinforce the social dimension of environmental sustainability. Naturally, as mentioned earlier, this implementation of sustainability will probably revolutionise the form of buildings, but this approach could be exploited by architects as an innovating tool to humanise and beautify their built structures.

The planet may be perfectly capable of sustaining all human needs, as long as we re-learn how to respect the demands of nature and how to focus our use of technology [1].

3.2 A new dynamic and interactive building form

As previously stated, nearly half of the energy derived from fossil fuels is consumed by built structures. The challenge for architects is to develop buildings that incorporate adaptive and responsive technologies, so as to reduce their pollution and running costs. Three-quarters of everyday energy use in buildings is accounted for, in more or less equal proportions, by artificial lighting, heating and cooling; but all these functions are now being revolutionised by new technology and new practices. Innovation is underway which can radically reduce long-term running costs and pollution generated by buildings.

Nonetheless, before moving on to a consideration of this new approach to building techniques it is important to put the whole issue in the context of a very different, but not unrelated idea: the notion of “sustainable design”, where human designers produce an architecture which is itself sustainable, rather than just an assembly of “sustainable” components.

Technology is the breakthrough which has revolutionised the process of designing low-energy buildings. Software already available can generate models that predict the air movement, light levels and heat gain in a building while it is still on the drawing board. This significantly increases our ability to refine those aspects of the building’s design, exploiting the natural environment to reduce its consumptions.

New technology is also giving buildings increasingly sensitive electronic sensors able to register internal and external conditions and respond to specific needs. New materials exist that can generate power, that can dynamically and adaptively change from highly insulating to transmitting and from opaque to transparent, that can react organically to the environment and transform themselves in response to daily needs and seasonal cycles.

Advanced glazing materials coming from scientific experimentation, for example, offer a wide range of options to enhance the optical and thermal characteristics of windows, and to improve comfort,
appearance and the energy related performance of building envelopes.

Amongst other, switchable façades technologies, which can adapt dynamically to the changing external climate conditions or can be switched according to internal needs of users, are a case in point [5].

As a matter of fact, switchable façades can be designed to adapt in an almost “living” way to variations in luminous and solar radiation levels and user requirements, so as to reduce the energy consumption of the building, to create a pleasant environment for the people who live inside, and to make use of natural, renewable energy sources in as environmentally compatible a way as possible (fig. 5).

Figure 4 – A switchable façade in action

Notwithstanding that, innovating switchable glazing represents just a tool to a totally new approach to building design, in which built structures need to minimise their confrontation with natural forces, respecting their laws and interacting with them. The challenge now is how to integrate these innovating technology into an equally innovating strategy for architecture.

To accomplish those objectives, the problem cannot actually rely only upon technological issues, but, rather, it should be referred to the realisation of buildings able to weave together the triad of environmental, architectonic, and human considerations, into a sustainable approach to design. As these three layers are integrated, we could finally evolve toward the realisation of a “living architecture”, one that more fully supports and engages life in all its forms.

As a matter of fact, it is the overall design of the building - structure, envelope, rooms, windows, etc. - and not technology for its own sake, that determines how much solar energy will be admitted, how daylight will be distributed, whether electric lighting will be needed, the amount of heat gain or heat loss, and whether there will be enough ventilation. Architectural design, thus, defines the degree of connection with the site, with environmental forces, and with the climate.

Through strategic design, the integration of novel climate change adapting building technologies and urban planning, we should exploit the interactions between human inhabited spaces and the dynamic of our surroundings in order to guarantee comfortable conditions into built environments with a more efficient use of energy, reducing greenhouse gas emissions and maintaining human biological rhythm in connection to the rhythms of nature.

Architecture has to change in response to environmental demands and the development of new high-performance materials. In this logic, the buildings of the future will be less like the immutable classic temples of the past and more like indeterminate, adaptable and floating structures that respond to daily changes in the environment and patterns of use.

This new architecture will obviously also change the character of the public domain. Actually, as external environment is an entity to interact with, buildings will become more permeable, and pedestrian could move through them rather than around them. With the same freedom and creativity that characterise a person facing changeable events, the “adaptive” building of the future will, hence, not be designed as a self-referential object, but rather it will be manned with the ability to change its functioning and adapt itself and its users to the changes in the environment.

In a sense, with the development and application of adaptive interactive technologies, the “form” in itself - here intended as the abstract crystallisation of an ideal beauty - might be considered as an heritage of the past. On its place, the more “plastic” and sustainable (in its wider sense) concept of interrelation, that implies the sensorial - and thus, aesthetic - involvement of the user, the architectural object and its context, into a process founded on a mutual exchange of information.

Built environments must be designed for flexibility and openness, working with and not against the now inevitable process whereby our environment is subject to a tangible and rapid change. On the other hand, even from a strictly functional point of view, as homes, schools, entertainment and work-places become less defined by their single purpose, one adaptable basic structure would probably be able, eventually, to accommodate different activities.

Aesthetics will be all but freed from association with the function that the building encloses? It may be, but assuming this new approach to design, it is the building system in itself - its craftsmanship, responsiveness and beauty - that will surely fast become the dominant criterion; the aesthetics of response, change and modulation will replace the fixed order for architecture, certainly representing one of the most promising issues of contemporary architecture.

The future is here, but its impact is only just beginning; working our buildings into the cycle of nature will return architecture to its very roots.

REFERENCES