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Retrospective Analysis of Sustainable Architecture: Mind-Mapping Development of Ideas and Expression

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Retrospective Analysis of Sustainable Architecture: Mind-Mapping Development of Ideas and Expression

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Abstract

This research focuses on the historical development of sustainable architecture. The study highlights the dynamic interrelation between ethics and aesthetics, it identifies the key concepts, trends that are relevant today in order to achieve harmonious co-existence between humans and nature. The article consists of six chapters that chronologically highlight the important developmental turns of environmentally oriented architecture: 1-collision between industrial and natural in the 19th and early 20th centuries, 2-at the edge of the modern movement, 3-environmental awakening in 1960s – 1970s, 4-the wind of change in 1980s, 5-the rise of sustainable architecture in 1990s and the emerging complexity of design, 6-sustainability in architecture as a global phenomenon. The concluding section summarizes and generalizes the findings. It also presents the existing problems, offering insights for the future development. The methodology of the research includes literature review, critical analysis, comparative analysis, and systematization. The mind mapping technique and timeline construction are applied as tools in the study to extract the core ideas and developmental shifts from the linear historical analysis.

Keywords: sustainable architecture, sustainability, environmental ethics, architectural expression, aesthetics, mind mapping.

Introduction

Currently, the urgent need to reduce negative ecological impacts require a rethinking of our interaction with the environment. Some researchers and thinkers note that even the current sustainable development paradigm is essentially limited and that it is no longer sufficient to maintain the *status quo* (Ehrenfeld 2008).

M. Skjonsberg (2011) compared architecture to science fiction: both have always been progressive in inventing ideas for the future. These days, there are a variety of concepts that go beyond the conventional paradigm of sustainable development and propose alternative approaches in the field of architecture. Scientific studies (Istiadji et al. 2018; Delancey 2004; Berardi 2013) have shown that the sustainability paradigm is shifting towards a systemic, dynamic, organic, holistic and non-linear approach. The emerging concepts of resilient, restorative, regenerative architec-

ture and others illustrate the effort to restore the lost connection with the natural world and to develop the co-existence between humans and nature in the urban environments of the future. Aesthetics has always played an important role in expressing beliefs throughout the history of architecture, and so it is interesting to examine the impact of evolving environmental attitudes on the expression of architecture. In order to better understand these dynamic processes, it is worthwhile not only to look at current development in the field of sustainable buildings, but also to analyze the past - the history of the development of what can be called environmentally friendly, responsible or sustainable architecture.

Visual experience is the first and probably the most powerful way of perceiving, appreciating and evaluating the built environment. The intuitive sense of aesthetics depends on individual perception, cultural background, beliefs, etc. Aesthetics can even be considered as "a form of knowledge that is gained through the senses" if we follow A. G. Baumgarten, the 18th century philosopher who coined the term "aesthetics" (Lee 2011, p. 7). M. Skjonsberg (2011, p. 23) follows the Greek notion of aesthetics and argues that ethics and aesthetics are interrelated because the visual sense of aesthetics and the feelings of "justice, well-being and satisfaction are all included in our sensorial sphere." Therefrom, this study defines aesthetics in architecture as a visual and sensory experience that reflects ethical attitudes and values of a particular group or population. This research focuses on the historical development of sustainable architecture and highlights the interrelation between ethics and aesthetics. Therefore, the aim of this study was to demonstrate how the aesthetics of sustainable architecture has evolved over time in relation to ethical attitudes towards the environment. To achieve this aim the following tasks were carried out:

- to highlight the changes in ethical attitudes towards the environment that have had an influence on the development of aesthetics of sustainable architecture;
- to present the most characteristic aesthetic directions of sustainable architecture in the course of its historical development;
- to reveal the influence of ethical attitudes towards the environment on the aesthetics of sustainable architecture.

Material and methods

The review paper is divided into six chapters that chronologically highlight the important developmental turns of environmentally oriented architecture from the onset of collision of the industrial and the natural in the 19th century to sustainable architecture as a global phenomenon in the 21st century. This study demonstrates both relevant twists and trends in the development of sustainable architecture based on analysis of literature and examples and the benefits of visualization techniques in research and how they can complement linear historical studies.

The methodology of the research includes a literature review, a critical analysis, a comparative analysis and a systematization. There are already valuable studies on the history of sustainable architecture (Attia 2018; Tabb and Deviren 2014; Wines 2000, 2019), however this study uses the mind mapping technique and the construction of timeline to systematize the analyzed material and highlight the key ideas that have emerged throughout the development of sustainable architecture and are relevant to the recent sustainable design paradigm. Mind mapping is the technique used in brainstorming and idea generation allowing deconstructing complex topics by creating graphical representation of constituent subtopics and related themes (Kernan, 2017); moreover, it allows easier determining and perceiving links between concepts; it is convenient for visual representation as well. C. Tattersall et al (2007) discussed the possibilities to use mind mapping in scientific qualitative research for such purposes as transcriptions of qualitative interviews and other types of analysis of qualitative data. This study is the example of mind mapping technique application in the qualitative analysis of development of architecture.

Results and discussion

Collision between industrial and natural in the 19th and early 20th centuries

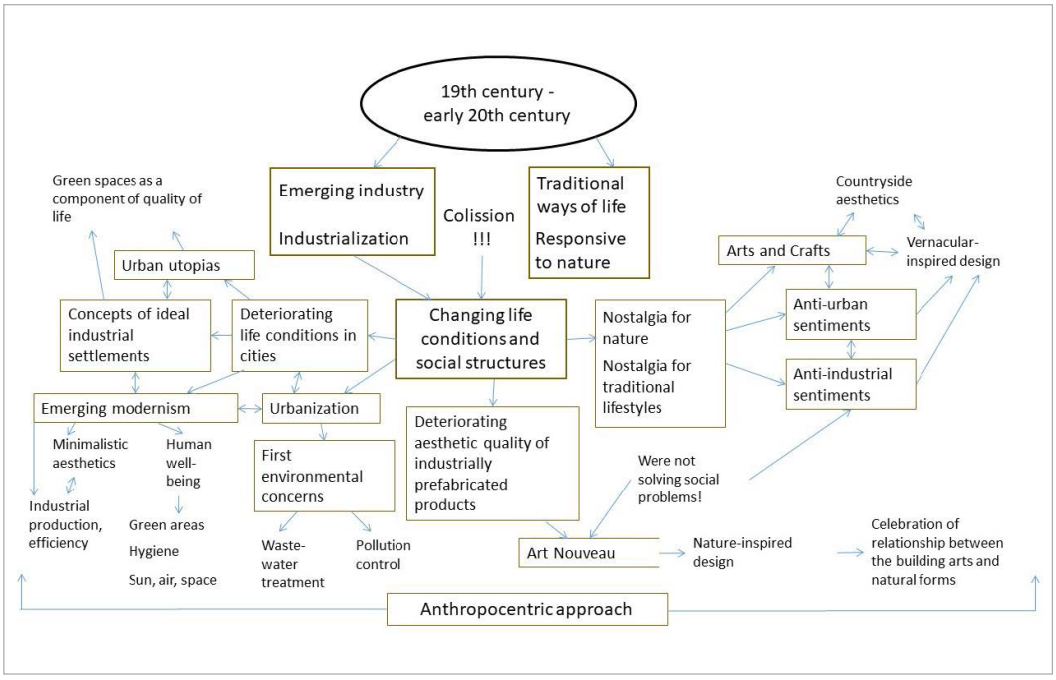
The 19th and early 20th centuries saw a sharp collision between emerging industry and traditional ways of life that responded to nature. Reactions to the changing conditions and patterns of life took place in all areas of life and creativity, including art, architecture, urbanism, philosophy, technological achievements, etc. The reactions related to the built environment consisted of a variety of approaches ranging from anti-urban and anti-industrial sentiments to urban utopias and concepts of ideal industrial settlements (Samalavicius 2008), which gradually caused the emergence of industrialization and prefabrication, as well as modernism in architecture and urban planning.

J. Wines (2000, p.22) argues that at that time the Arts and Crafts and Art Nouveau movements were the last architectural trends "to celebrate the relationship between the building arts and natural forms." Both short-lived movements, which were quickly displaced by Modernism, could be compared with contemporary biophilic design approach, which suggests using biomorphic forms and patterns, naturality of materials in origin or form, complexity and order (Browning et al. 2014), connections with vernacular and rural aesthetics and craftsmanship in the case of the Arts and Crafts movement.

However, the Arts and Crafts and Art Nouveau were dedicated to please the middle and upper classes; meanwhile, workers lived in miserable conditions in the polluted and crowded industrial cities. These negative consequences of expanding industrialization and urbanization on the quality of life led to the emergence of environmentally conscious concepts in the 19th century (Zaleckis and Vitkuviene 2011). For example, the British physician B. W. Richardson was one of the first to describe the concept of an imaginary city of health – Hygeia (1876). He raised the issues of air pollution control, water and sewage treatment, proposed green areas of the city - avenues of streets and public gardens (Richardson 1876). In 1898, E. Howard's Garden City concept and its implementations in Welwyn and Letchwort emphasized the differences between crowded, polluted, unhealthy urban environments and attractive, green garden cities. Green spaces have become associated with better living conditions at that time (Alexandri 2007). The dominant aesthetic features of the numerous implemented garden cities were the small settlement scale, traditional English housing architecture and greenery (Díez-Medina and Monclus 2018).

Fig. 1

Mind mapping of the development of architecture in the 19th - early 20th centuries illustrates underlying anthropocentric concerns and emerging trends of a nature-inspired, vernacular-inspired and minimalist aesthetics



In summary, both nature inspired (e.g. Art Nouveau) and environmental quality-oriented (e.g. Garden city) trends were based on the anthropocentric approach, dominated by human needs – aesthetic pleasure in the first case and health and productivity in the second (Fig. 1). Progressive industrialization - the Machine Age, represented the dominant "technocentric and anthropocentric view of human habitat" (Wines 2000, p. 16). However, it is interesting to note that nature-inspired, vernacular-inspired, and greenery-oriented design trends that had emerged in this collision between industrial and natural will continue to reappear throughout the 20th and 21st centuries.

At at the edge of the Modern Movement

Although the first half of the 20th century and the post-war years can be characterised by the mechanistic-reductionist approach to the environment, the technocentric worldview, and the International Style, interesting environmental architectural and ethical approaches have emerged beside this mainstream movement - bioclimatic design, Organic architecture, Regionalism, reverence towards nature and the spirit of the place (Fig. 2). The paradigm of bioclimatic architecture exemplifies the first conscious considerations about climate responsive design - its emergence in the early 20th century became the starting point for the development of environmentally friendly modern architecture (Istiadji et al. 2018; Attia 2018). Bioclimatic projects included experimentation with building orientation, solar shading, passive cooling strategies, solar technologies (Watson 1998) and were usually focused on the search for better hygienic conditions in buildings and healthier environment. Despite the initial attempts to ensure favorable microclimatic conditions both inside buildings and outdoors, the concept of bioclimatic architecture was defined only in 1963 by architect V. Olgyay (Bondars 2013).

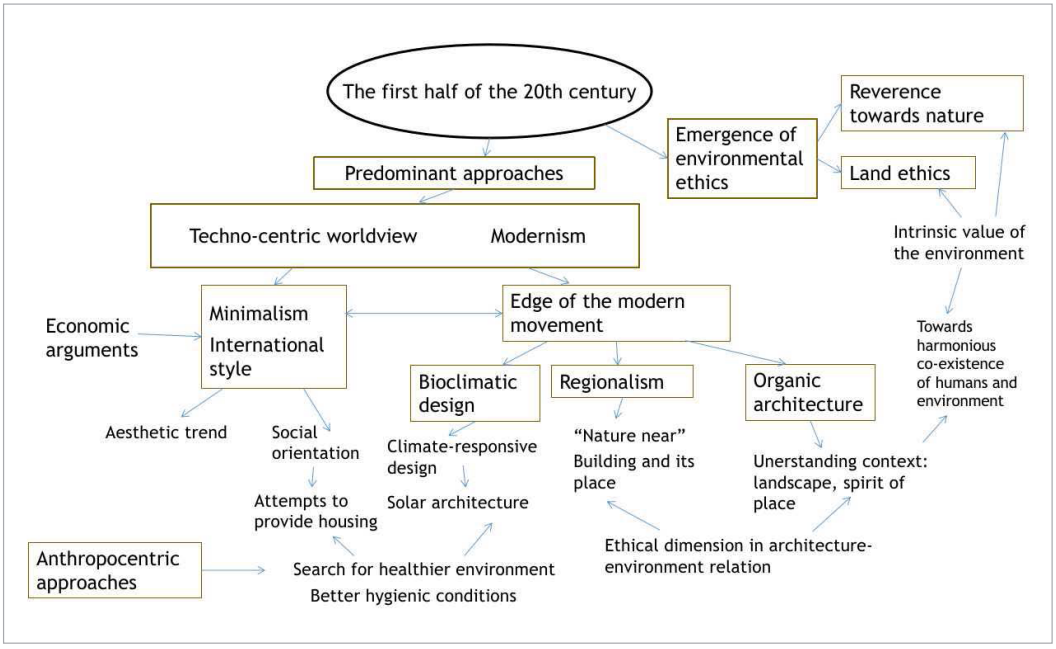


Fig. 2

Evolution of architectural expression at the edge of the Modern movement and the emerging environmental ethics in the first half of the 20th century

Moreover, the works of some architects at that time embodied the emerging architectural philosophy that introduced an ethical dimension into to the relationship between architecture and the environment. F. L. Wright's holistic approach and consideration of the sense of place, R. Neutra's (1989) connectedness with nature – "Nature near", A. Aalto's sensitivity to building in its place. Regionalism and the precautionary principle (Speck 2012) were like echoes of the philosopher's A. Leopold's (1949) "Land Ethic", reflecting a sensual and reverent attitude towards the environment. The concept

of Organic architecture by F. L. Wright stands out in this period. According to J. Wines (2000, 22-23 p.), F. L. Wright's "work shaped the fundamental principles of integrating architecture with its context in this century" and is still relevant to contemporary perspectives on sustainability, biophilic design and other environmentally friendly design patterns (Sassi 2006; Brophy and Lewis 2011; Browning et al. 2014). According to S. Graff (2018), F. L. Wright believed in "a sustainable ecosystem comprising nature, the built environment, and human life, in which each component supports the other components and all thrive as a result." It is worth recalling F. L. Wright's philosophy: a unifying element between ethical values and aesthetic qualities of the built environment – "the Spirit" or the "Third dimension" – as he called the sense of a place. It illustrated not a thing itself, but the character of a thing, that responds to the surrounding environment and has the intrinsic value (Graff 2018).

To some extent, those century-old concepts of F. L. Wright reflect the idea of sustainable co-evolution of the natural and human worlds (including the built environment), that is the key concept of regenerative design - the latest and, at the moment, somewhat futuristic trend in architectural design. However, although some architectural pioneers considered the wider context of the human-nature relationship, the dominant trend of this period was bioclimatic architecture and solar design. These architectural projects exemplify an understanding of climate, as well as active and passive design strategies (Watson 1998). These trends were dominant until the environmental crisis reached its peak in the 1960s and 1970s.

Environmental awakening in 1960s - 1970s

Environmental awareness had already taken root in architecture and related fields during the environmental crisis of the 1960s - 1970s. For example, in 1957, inventor, architect, designer and futurist Buckminster Fuller proposed the holistic concept of "comprehensive anticipatory design science," which insisted on the "effective application of the principles of science to the conscious design of our total environment, making Earth's finite resources meet the needs of humanity without disrupting the ecological processes of the planet" (Ryker 2007). Landscape architect Ian McHarg (1969) encouraged professionals to "design with nature".

Increasing concerns about endangering ecosystems, dwindling natural resources, and pollution led to a stronger environmental movement in the 1960s and 1970s, with awareness-raising publications such as R. Carson's book "Silent Spring". The 1960s youth movement in America was the first wave of the Green movement (Wines 2000; Istiadji et al. 2018). The first Earth Day was celebrated in April, 1970. Radical ideas of a non-anthropocentric environmental ethics had emerged in early 1970s. Norwegian professor A. Naess developed the concept of deep ecology, in which he raised ideas of the total interconnectedness of humans, other living things, and the environment (Wines 2000; Levesque 2016). J. Lovelock formulated the Gaia hypothesis in 1972, in which he defined the Earth itself as a self-regulating living system (Radfor 2019). In 1972 United Nations Conference on the Human Environment was held in Stockholm. This conference signaled the birth of environmental diplomacy and acknowledged that economic development and environmental impact are inseparable as well as proposed the concept of ecological development (Chasek, 2020).

Internationaly acknowledged ecological development ideas and the oil crisis in the US in 1973 and 1979 encouraged the search for architectural innovation in terms of clean energy and energy independence. This led to architectural experiments that included passive and active solar design, the use of wind and integrated energy systems, daylighting strategies (Borasi et al. 2009; Donoff 2016). Ecological housing ideas were explored in many unexpected ways in the 1970s by amateurs, ecological communities, and professionals (Sho 2008). For example, M. Reynolds designed Earthships, the off-grid, self- sufficient structures built from recycled waste materials such as old tyres, bottles, and cans (Mead 2020; Sho 2008); (Sho 2008; Miller 2016). The overall architectural aesthetics of such experiments could very often be described as small-scale, handmade, irregularly shaped, and emphasising the use of recycled and natural materials.

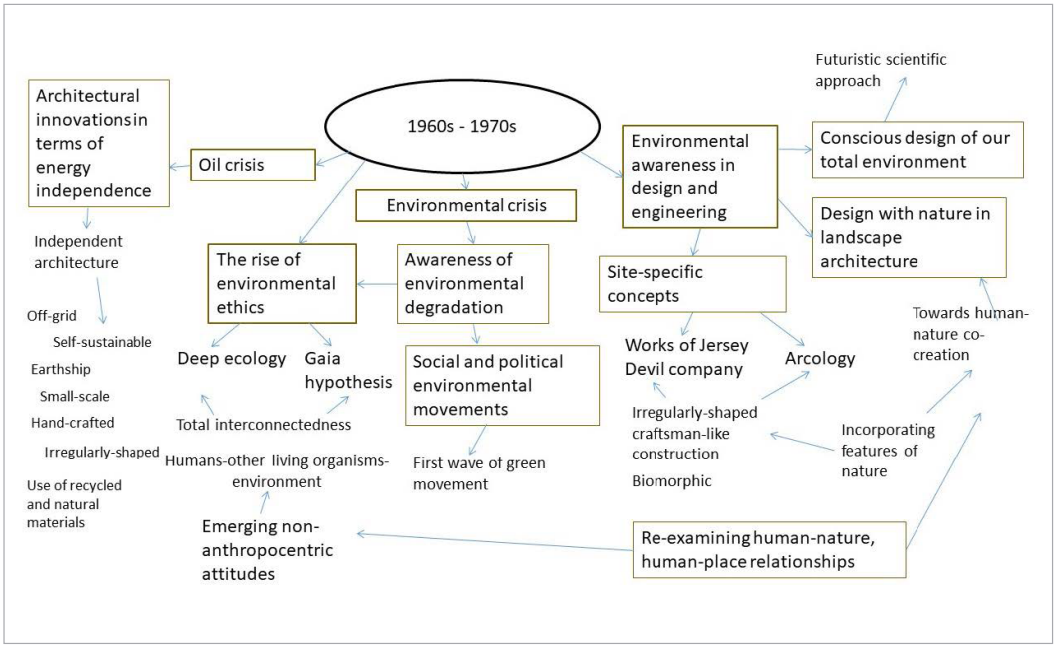


Fig. 3

Environmental awakening and its influence on the development and expression of architecture, leading to the emergence and spread of environmentally conscious design approaches and some radical, eccentric architectural experiments

Other radical architectural experiments of the period reexamined human-nature and human-place relations. In 1969, architect P. Soleri introduced the concept of Arcology – the fusion of architecture and ecology. He implemented this concept in an experimental, compact, car-free eco-city that persists today as an urban laboratory (Eidt 2013; Arcosanti n.d.). Jersey Devil company promoted site-specific, design inspired by the eco-movement. By designing and building themselves, they proposed on the one hand radical, on the other – simple approach to vernacular, craftsman-like way of construction (Sisson 2016).

To sum-up, in the 1960's and 1970's, holistic and non-anthropocentric environmental ideas, beside the ecological crisis, stimulated a series of architectural and even urban design experiments as an emerging radical and eccentric alternative to the prevailing technocentric modernistic worldview and designs (**Fig. 3**).

The wind of change in 1980s

Non-anthropocentric and holistic views continued to develop in the field of environmental ethics during this period. P. Taylor argued that every entity existing in nature, whether it has a consciousness or not, itself has intrinsic value and deserves moral respect. T. Regan stood for animal rights (Brennan and Lo 2015). W. Fox (2007) introduced the theory of "responsive cohesion," which placed moral priority on the preservation of ecosystems and the biophysical world. The establishment of and growing memberships in environmental organisations such as Greenpeace, Environmental Action, the Sierra Club, Friends of the Earth, and others illustrate the increased attention to the need on environmental protection in society (Wines 2019). The 1984 German exhibition Grün Kaputt expressed criticism of the aesthetic degradation of the built environment, reflected in a loss of greenery, uniformity of architecture, and synthetic building materials (Werthmann 2007).

Ecological design ideas began to occur in emerging architectural environmentally conscious design concepts, such as permaculture, biophilic design, restorative environments, passive house, and others. The permaculture design system was offered in 1978 by B. Mollison and D. Holmgren. They proposed design patterns based on a holistic approach where human well-being and environmental protection are equally important (Istiadji et al. 2018; Nelson 2016). E. O. Wilson for-

mulated the Biophilia hypothesis (1984), which became the basis for biophilic design. S. Van der Ryn and P. Calthorpe suggested creating buildings and communities that are sensitive to place, climate, and the flow of human interactions (Calthorpe and Van der Ryn 1986). S. Owens, in her book "Energy, Planning and Urban Form" (1986) explained different scales of sustainability ranging from global to product scale. W. Feist built the first passive house in 1988 (Feist 2014). American architect M. Wells began designing environmentally-friendly and visually almost invisible underground and earth-sheltered buildings, which he called "green alternative to the asphalt society" (Steinfeld 2003). The architectural work of another American architect, W. McDonough, was based on his concept of "ecologically intelligent design", which includes aspects of manufacture, use, and disposal: the selection of raw materials, the transportation of materials to the factory, the manufacturing process, the durability of the goods produced, the usability of the products, and the potential for recycling (Wines 2019). He was the author of the first green office in the U.S. - Environmental Defense Fund Building in New York City, built in 1985. W. McDonough's design process later became the Hanover Principles (1992) and the Cradle to Cradle concept in 2002 (Vale and Vale 2014; McDonough n.d.; Braungart and McDonough 2002; Wines 2019).

Research and institutionalisation of the concept of "sustainability" also began during this period. The Rocky Mountain Institute was founded in 1982 by A. Lovins and H. Lovins as a research centre dedicated to sustainability studies and was based on the "whole system" approach, with a particular focus on innovations for energy and resource efficiency (Wines 2019). The terms "sustainability" and "sustainable development" became common knowledge in 1987, when the World Commission on Environment and Development (WCED) published a report with the official title "Report of the World Commission on Environment and Development: Our Common Future", also known as "Brundtland Report". This report presented the concept of "sustainable development" - development that meets the needs of the present without compromising the ability of future generations to meet their own needs - and its guiding principles as they are commonly understood today. It is evident that the definition of sustainability clearly reflects the human interest side (Istiadji et al. 2018) and could be referred to as an anthropocentric approach.

Architectural expression in general also underwent changes in the late 1980s. In 1986, the Architectural Review published a monographic number entitled "The New Spirit" that showed a sense of the new cultural climate (Puglisi 2009). In 1988, Ph. Johnson together with M. Wigley organised the exhibition titled "Deconstructivist Architecture" at the Museum of Modern Arts (MoMA). They published an exhibition catalogue that gathered the works of seven promising architects - P. Eisenman, F. Gehry, Z. Hadid, R. Koolhaas, D. Libeskind, B. Tschumi, and the firm Coop Himmelblau (led by W. Prix). These architects shared similar approaches and achieved similar results (Fiederer 2017). Along with their contemporaries, they brought "an extraordinary impulse to contemporary architecture" (Puglisi 2009, p. 63) and "proved to be some of the most influential architects of the late 20th century to the present day" (Fiederer 2017). Accompanied by technological innovations, the so-called Starchitecture became the dominant architectural movement. Some critics note selfishness, egotism, ecological neglect and ignorance of the context in their iconic architecture, as well as manipulation with the term "green" and its use only in ways that do not compromise the aesthetic expression of Starchitecture (Stephens 2009). Nevertheless, it can be stated that the aesthetic experimentation of architects in the 1980s expanded the scope of architectural expression and this emerging freedom of expression could later be taken up by ecologically conscious architects.

In summary, the 1980s can be seen as a period of change in many areas related to sustainable architecture: philosophy, environmentalism, architectural trends, design principles and technical possibilities (Fig. 4). However, environmentally conscious design was not yet prevalent in the architectural context in the 1980s.

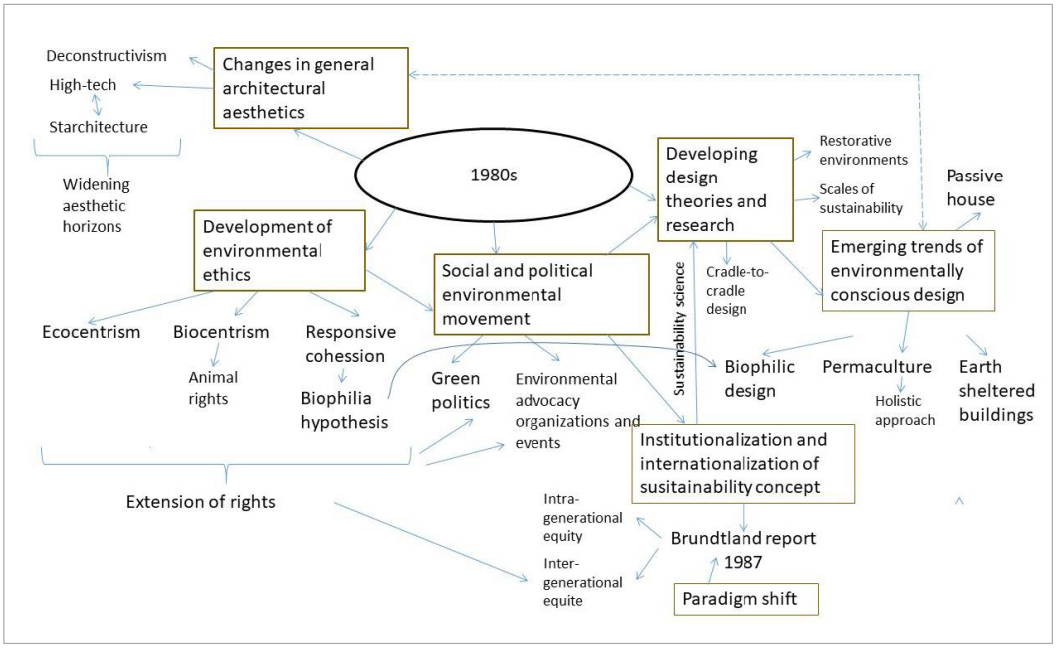


Fig. 4

Emerging trends of environmentally conscious design reflected ethical paradigm shift in the development of societies and illustrated the climate of expanding horizons of aesthetic expression in architecture

The rise of sustainable architecture in the 1990s and the emerging design complexity

In the early 1990s, environmental problems in the form of unusual weather patterns, soil pollution, droughts, oil spills, and increased incidence of disease were directly felt by the societies and became a major concern on the international political agenda (Wines 2000; Istiadji et al. 2018). The definition and understanding of sustainable architecture evolved during this period through the work of forward-thinking architects and new design concepts. S. Van der Ryn and S. Cowan presented a set of ecological design principles that can be applied in buildings, landscapes, cities and technologies (Van der Ryn and Cowan 1995). O. Arup's thoughts on "total design" focused on the building as a whole. The integrative design practice of O. Arup himself exemplified the collaboration between architects and engineers and how the building design team should work to achieve a "more complex whole" (Mang 2001; Uihlein 2016). Indeed, sustainable design and architectural design in general turned to increasing complexity during this period.

Since the 1990s, the advances of digital technologies, tools and design methods such as computer-aided design (CAD), computer-aided manufacturing (CAM), building energy calculation programs including dynamic space and daylight analysis, improved environmental technologies, etc., led to the emergence of new, almost unlimited possibilities in architecture (Wines 2000; Puglisi 2009; Tabb and Deviren 2014; Maciulis 2013). Both the spread of the concept of sustainability and technological advances brought new approaches to architectural expression and aesthetics. High-tech architecture, which developed in the late 1960s (Jencks 1995), acquired new eco-tech and organi-tech features (Tabb and Deviren 2014).

High-tech with its directions, such as slick-tech (emphasised hyperbolization of surface aesthetics), embodied the zeitgeist reflected in the adaptation and use of high technologies for engineering, production, and even architectural expression (Maciulis 2013; Davies 1988). To illustrate, the eco-tech trend intermingles high technologies and paradigm of sustainability. However, Ch. Jencks argues that technology and machine aesthetics "still predominate over nature and the organic," so it cannot be said that high-tech architecture has shifted into organi-tech. Rather, it has been a "slide" in that architectural direction (Jencks 1995). Another direction of technical aesthetics

can be traced in the evolving architecture of this period – low-tech hybrids that developed in the 1990s (Tabb and Deviren 2014). Low-tech were mostly small-scale residential buildings, that, although not new in 1990s, followed passive design strategies such as natural ventilation, controlled solar gain, night cooling, rainwater collection, etc., as well as use of local materials. Low-tech hybrids usually incorporated both high-tech and low-tech solutions (Maciulis 2013; Shari 2018).

Some visionary architectural sustainability concepts of the 1990s based on the properties of natural systems are still influential today. For example, the regenerative design concept of J. T. Lyle (1994), professor of landscape architecture, provided "12 regenerative strategies" – practically tested ecological design strategies for water use, land use, energy use, and building design. P. Mang (2011) illustrates the definition of the word "regenerate" as containing three key ideas: a radical change for the better; the creation of a new spirit; the return of energy to the source. In 1997, biologist J. Benyus introduced the concept of biomimicry – "a practice that learns from and mimics the strategies found in nature to solve human design challenges" (Biomimicry Institute 2021). Biomimicry was introduced into the the field of architecture, in which attempted to mimic both natural processes and forms. For example, W. McDonough's and M. Braungart's "cradle-to-cradle" design principles model a waste-free, closed-loop design life-cycle (Wines 2019). The BREAM (1990) and LEED (1998) certifications brought some measurable criteria to the design and construction of environmentally conscious buildings (Smith and Parmenter 2016).

Meanwhile, parametric architecture opened new possibilities in creating organic architectural forms. The first architect to use computers to generate architectural forms was G. Lynn, who is famous for his "blob" and later for "folding in architecture" - experiments driven by computer generated forms. The architectural expression of "blobby" buildings has an organic, amoeba-shaped building form, an undulating, curvilinear building design (Craven 2020). Unlimited possibilities of architectural imagination and organically shaped experiments also appeared in virtual space. The expression of architecture became possible outside the physical world. Digital software and advanced fabrication methods enabled the opportunities of complex biomimetic and biomorphic architectural forms that were previously impossible.

The expression of ecological aesthetics has expanded greatly since the 1990s. The influence of earlier earth-sheltered structures led to a literal greening of architecture. Horizontal and vertical vegetation was often used in sustainable architectural projects. Vegetation systems of buildings have created habitats for wildlife - insects and birds, in addition to their other benefits such as mitigating the heat island effect, created habitats for wildlife – insects and birds. Thinking about how wildlife can live in dense urban structures brings us closer to implementing human-nature co-evolution in urban settlements (Tabb and Deviren 2014).

In summary, the 1990s brought increased design complexity, new forms and the search for sculptural, irrational forms (Lupeikis 2007) and their applications in design (Tabb and Deviren 2014). The emphasis on ecological dimensions of architectural design and innovations of environmental technologies led to a more technologically oriented architectural sustainability, while aesthetic expression expanded the earlier boundaries of architectural imagination (Fig. 5).

Sustainability in architecture as a global phenomenon

Sustainability in architecture has become a global phenomenon since the turn of the millennium, in which the horizons of sustainability are constantly expanding. If the concept of sustainability in the 20th century expressed the idea of preserving (literal meaning of the word "sustain") the current situation – not causing more damage, the 21st century expresses the need to go beyond sustaining towards restoration of damage, regeneration of systems and co-evolution with nature (Berardi 2013; Robinson and Cole 2015). "The new sustainability" approach discussed by A. D. Istiadji et al. (2018) demonstrates the ongoing shift in the sustainability paradigm. The systemic - holistic ap-

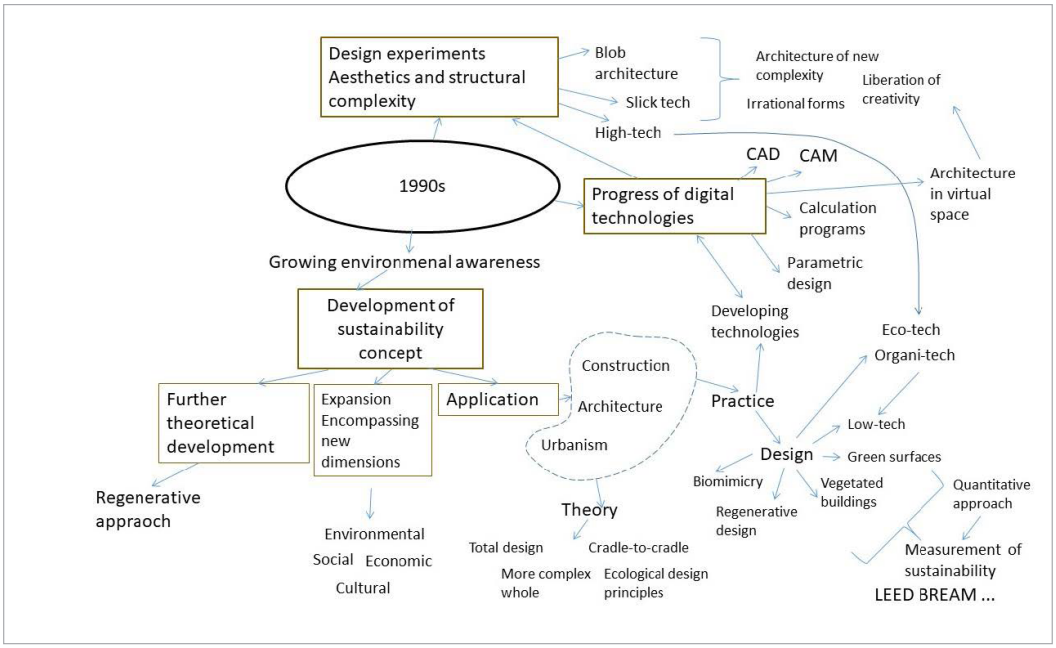


Fig. 5

Application of the concept of sustainability in construction, architecture and urbanism, influenced by the progress of digital technologies and the emerging architecture of new complexity

proach, which takes into account the mutual benefits of living with nature, is gaining acceptance in place of the long-prevailing anthropocentric approach that satisfies only the needs of the human race. U. Berardi (2013) encourages thinking in larger contexts by emphasising the importance of the interrelationship between the building and its environment. The influential architect B. Ingels in his TED lecture entitled "Hedonistic Sustainability" (2011) encouraged architects to become "designers of ecosystems" that encompass ecology, economy and resources (Ingels 2011). Network thinking that encompasses architecture, landscape, technology, culture, nature and ecology becomes crucial for the development of sustainable living environments where buildings are only one part of the larger whole (Tabb and Deviren 2014).

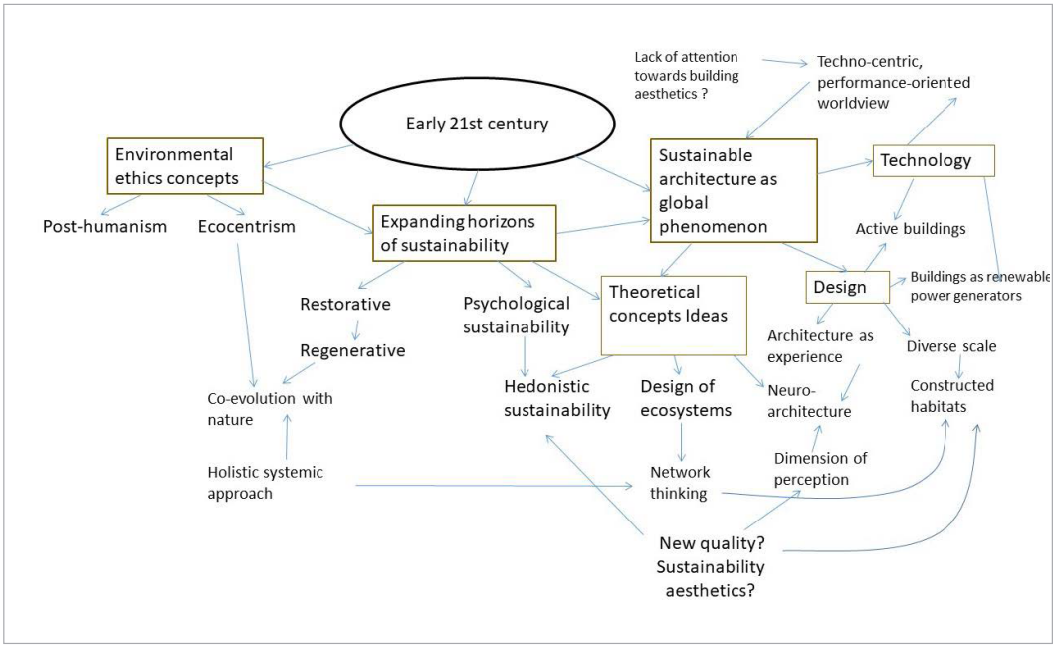
The understanding of architecture as a sensory experience is reinforced in new considerations of the sustainability paradigm, which includes the dimension of perception and brings the notion of psychologically sustainable architecture (Lindal and Hartig 2013; Ramzy 2015; Bond 2017). M. Bond (2017), in his article in BBC Future, summarizes the research of neuropsychologists, psychologists, architects and urban planners who have studied the relationship between the environment and people and introduces the term "neuro-architecture" (Lindal and Hartig 2013). M. Bond argues that little attention is still paid to the potential cognitive effects of the environment on humans in the design of buildings and urban structures, even though we already know their psychological significance (Bond 2017).

The diversity of sustainable architecture has greatly expanded, ranging from small to large scales, from new construction to renovation of existing structures, both high-tech and low-tech, in various environments. Architectural trends blend together and adapt the newest technological advances. Buildings become active in time – media, hypersurfaces, kinetic architecture, independent building envelopes mediate temperature, reacting to light or rain (Cao 2019). Practices of energy autonomous architecture are spreading rapidly – innovative buildings become "renewable power generators" (Droege 2012; Sobek 2018).

While sustainable design used to focus mostly on advancing form, materials and technology of individual buildings, projects of much a larger scale began to emerge. The 21st century has brought with it the need for a new integrative approach to contextual design, where buildings are no longer

Fig. 6

Sustainable architecture is becoming a global phenomenon in the early 21st century. The sustainability concept is evolving towards restorative, regenerative approaches and living environments as constructed habitats; however, the expected qualitative aesthetic turn of sustainable architecture seems to be hindered by quantitative technocentric performance-oriented approaches



considered as individual and isolated objects. G. Mangone and P. Teuffel (2011) suggested redefining buildings as "constructed habitats" that are interconnected with the surrounding ecology. The built and natural environment, people as well as other living organisms, regionally specific aspects such as "surrounding topography, indigenous vegetation, cultural history, and territorial idiosyncrasy" (Wines 2008), and even natural processes are considered as an integrated whole in recent thinking on sustainable architecture. Large number of new experimental eco-settlements, such as the eco-city in Montecorvo, Spain by MVRDV in collaboration with GRAS (2008), Solar City, Linz, Austria (2001-2005), reflects a more systematic approach. China claims to be developing 285 eco-cities – one of which is Tianjin. However, detailed research revealed that "eco" is often used as a trendy cliché for marketing purposes. To illustrate this, W. Shepard compared Tianjin and London in measurable sustainability criteria. His study showed that London outperformed Tianjin as an eco-city, although we do not consider London as an eco-city (Shepard 2017). The question is what can be called a truly sustainable building or city and whether they reflect the concept of sustainability through their aesthetics.

Although the aesthetic and coevolutionary importance of the built environment has been highlighted in many studies, the focus on reducing use of energy and other resources still overshadows aesthetic and psychological dimensions of sustainability. Some initiatives such as Living Building Challenge (2000), seen as an extension of LEED, presented the exact standards to measure sustainability. It deals with seven performance categories: Site, Water, Energy, Health, Materials, Equity and Beauty, and finally included ethic, aesthetic and co-evolutionary principles in the evaluation of sustainable design.

There are a variety of aesthetic classifications (Wines 2000; Guy and Farmer 2001; Sauerbruch and Hutton 2011, Di Carlo 2016 and others) that show the diversity of trends and the difficulties in classifying sustainable buildings according to artistic expression. Although, there are examples of innovative aesthetics in sustainable architecture, these buildings are exceptional and rare. Currently, most sustainable buildings that receive the highest certification rates from LEED and BREAM, often do not have exceptional aesthetic expression as sustainable buildings. The strong influence of rationality and functionality of modernism is still felt in contemporary architecture.

Nevertheless, ten of the most sustainable buildings announced each year by the AIA (AIA 2019) illustrate that the search for sustainable aesthetic expression is ongoing.

Conclusions

This study has highlighted the important twists and turns in the development of sustainable architecture, from the first environmental concerns to emerging environmentally conscious design trends and to sustainable architecture becoming a global phenomenon (Fig. 7). The mind mapping and timeline construction techniques that complemented these linear historical studies allowed us to distinguish prevailing anthropocentric and alternative non-anthropocentric currents of thought that had influenced each other and the expression of environmentally conscious architecture. The timeline shows that both currents were constantly expanding the field of moral concerns.

The study enabled to distinguish several reflective periods whose influence was important for the development of sustainable architecture: the period of bioclimatic architecture in the 1900s-1960s, the experimental architecture of the 1960-1970s, the period of change in the 1980s, the establishment of sustainability in the1990s, and the current trends since the 2000s. The eco-friendly architectural trends that have emerged still exist today, though they are often heavily influenced by modernist trends. The mind-mapping technique and the construction of a timeline allowed us to group the aesthetic trends of environmentally friendly and sustainable architecture into several evolving trends (Fig. 7): nature-inspired architecture and technology-inspired architecture (considering both advanced and vernacular technologies). These trends tend to influence and converge with each other and integrate in the projected future development in the human-nature co-creation of constructed habitats. It should be noted, however, that contemporary sustainable buildings certified and highly rated by LEED or BREEAM often lack distinctive and meaningful architectural expression. Nowadays there are almost unlimited opportunities for architects to express their creativity, whether in a physical or virtual space. Therefore, the study of sustainable architecture aesthetics can trace important trends or exceptional examples of how architects envision the pursuit of sustainability, and provide successful design strategies that can be used as a further source of inspiration.

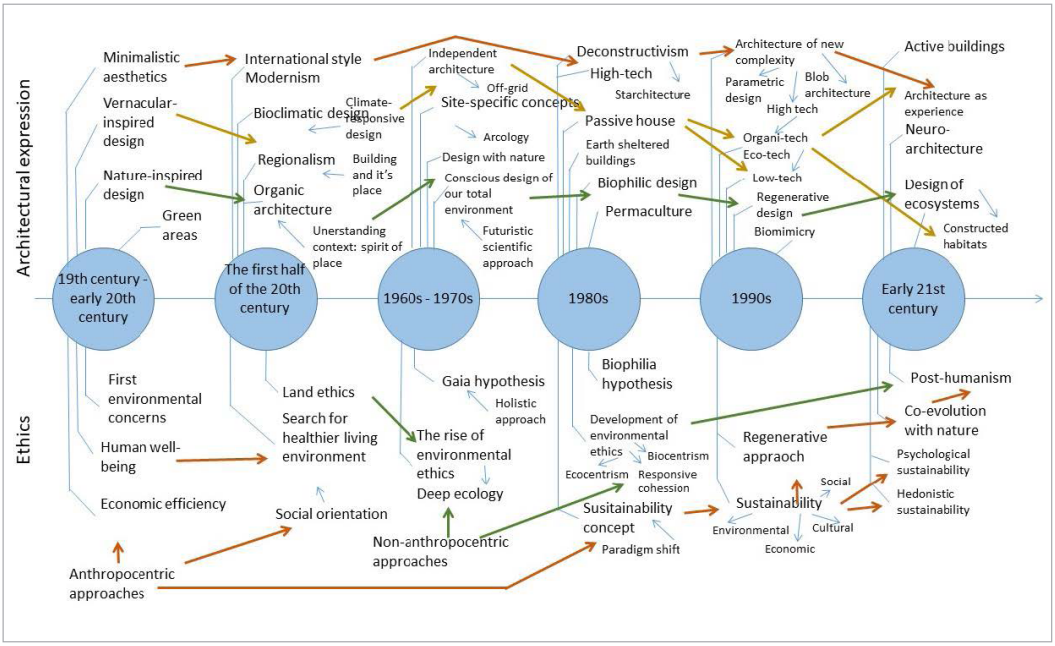


Fig. 7

Timeline of the emergence and development of sustainable architecture, showing the important currents of thought (anthropocentric (orange arrows) and non-anthropocentric(green arrows)) and design (technology-inspired (advanved technology inspired – orange arrows, vernacular technology inspired – yelow arrows) and nature-inspired (green arrows)) moving towards the foreseen integration in the co-creation of humans and nature in the constructed habitats

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