

Received 14 July 2020; accepted 12 April 2021
Available online 23 April 2021

The Effect of Time and Form on 21st Century Architecture [FOURTH DIMENSION]

Gehan Ahmed Elsayed

Associate prof. head of architecture department modern university for information
and technology
gehanelsayed2@yahoo.com

ABSTRACT

Dynamic configuration is the virtual applications and the innovation which create a wide range of sustainable buildings and spaces. In the virtual world, the conventional fourth dimension (time) is substituted by the element of movement (both 'physical and mental). Although the fourth dimension was known long ago since the medieval times, it was only studied in the nineteenth-century mathematically. If we look at the social context, we explore the biographies and works of the main characters in the nineteenth and early twentieth centuries, one shall notice that ethics and religion merely affected the study of the fourth dimension.

The liability issue is that green architecture or sustainability was described in the form of micro-climate environmental concepts; disregarding the other features, particularly that relate to Dynamic Configuration (4th dimension) which could affect the form of architecture to achieve sustainability.

Thus, the paper aims to concentrate on these features and bring its variable items as a type of application from contemporary architecture to be considered as an unlimited datum of ecological resilience.

The paper methodology is a descriptive and analytical method which used to prove that this sort of building was planned for an ecological model to fulfil the necessities for sustainability.

Finally, the paper resulted in; time and space have a strong relationship where motion in architecture expressed the time factor, and a fourth dimension 'Time' became part of architectural design which can improve the sustainability and affect building innovation to put creative forms and designs while respecting the surround environments.

Keywords:

time - form - ecological Sustainability – environmental sustainability.

الوقت والشكل على عمارة القرن الواحد والعشرين

الملخص

يعد التكوين الديناميكي نوع من التطبيقات الافتراضية والابتكارات التي تخلق العديد من المباني المستدامة. وفي المجال الافتراضي، يتم استبدال البعد الرابع التقليدي (الوقت) بعنصر الحركة (كلاهما "المادي" والمعنوي). على الرغم من أن البعد الرابع كان معروفاً منذ زمن بعيد حيث العصور الوسطى، إلا أنه لم يدرس رياضياً إلا في القرن التاسع عشر. وبالنظر للمحيط الاجتماعي، فسوف نكتشف ذلك في أعمال الرواد في القرن التاسع عشر وأوائل القرن العشرين. وسوف نلاحظ أن المبادئ الدينية والأخلاقية قد أثرت بشدة على دراسة البعد الرابع.

تتمثل القضية البحثية في وصف العمارة الخضراء أو الاستدامة في شكل مفاهيم بيئية مناخية مع تجاهل المميزات الأخرى للعمارة الخضراء وخاصة التي تتعلق بالتكوين الديناميكي (البعد الرابع) في المباني لتحقيق الاستدامة البيئية.

ولهذا، تهدف الورقة إلى التركيز على الإمكانيات المتعددة للعمارته الخضراء وتقديم عناصرها المختلفة والمتغيرة كأمثله تطبيقه من العمارة المعاصرة حيث تعتبر مرجع للمرونة البيئية.

المنهجية البحثية المتبعة هي منهج وصفي وتحليلي لإثبات أن هذا النوع من المباني (المباني ذات التكوين الديناميكي) قد تم إعداد ك نموذج بيئي يلبي متطلبات الاستدامة.

وفي النهاية، تنتهي الورقة البحثية الى عدد من النتائج منها أن هناك علاقة قوية بين عامل الوقت والفراغ، وأن الحركة في العماره تعبر عن عامل الوقت، ليصبح البعد الرابع "الوقت" جزءًا من التصميم المعماري الذي يحقق الاستدامة ويشجع على الابتكار وعلى خلق أشكال وتصميمات إبداعية تحترم البيئة المحيطة.

الكلمات المفتاحية: التكوين الديناميكي – التنمية المستدامة – الإستدامه البيئيه – التشكيل فى العماره

INTRODUCTION

Architecture usually integrates development and technology with traditions while adjusting to new materials and systems of fabrication. All the time, architecture is the intermediation between system, the image, and the scene that culture presents at each moment. (Marques & Loureiro, 2013)

Sustainable design is an integration of architecture with other engineering departments. At the same time, it worries about the aesthetics of principles of architecture design, (proportion, scale, texture, shadow, and light, massing) the design team should concentrate on long-term costs: ecological, economic, and human.

Sustainable Development depends on examples of creation and utilization that can be sought after into the future without corrupting the human or nature. It is a form of resource that intends to address human issues while conserving the environment. So, these requirements can meet both the present and the future. (Marques & Loureiro, 2013)

The sustainable development's argument depends on the hypothesis that social orders need to achieve three kinds of capital (economic, social, and natural), which might be non-identical, and its use may be irreversible. Although the integration of economic, social, and natural capital exists, natural capital is the most important.

Environmental Sustainability is a way to ensure that recent techniques of dealing with the environment are linked to the preservation of the native nature.

To fulfill the contemporary ethos, building materials ought to be developed in an ecologically friendly way, consequently affecting the characteristics of the surrounding urban environment; fulfilling the requests for sustainable power hotspots needed for warming, cooling, water, lighting, and management.

At the present time, the form of buildings must fulfill the call of sustainability. The architecture with its stress on sustainability is rarely devoted to more subdivision of exterior and interior spaces through putting simulated devices on building facade, for example, solar panel, wind turbine, and novel architectural envelope elements.

The question is: will this sort of building devices planned for the ecological model fulfill the necessities for sustainability? Or is it fulfill the needs for ecoefficiency?

Recently, architects are opposed by a further difficult challenge from the environment: climatic change. There is a cumulative concern in the innovative technique of creating an architectural envelope or facade. It inspires and motivates research on the analysis of the morphogenetic process between forms and dynamic forces of the environment. It also proposes that the architectural design combining the matters of 'nature' (e.g. Airflow, Light, and Heat) in a reproductive way, may cause a more receptive form to the environment. (Chiarella, 2004)

So, liability issues concentrate on aspects and factors relating to the design, structure, manufacturing, and examination of systems and materials in order to stimulate comprehensive proficient design standards, thorough understanding of building lateral envelope design methods and construction systems since they are a serious aspect of architectural training. When building lateral envelope problems arise. (Squires & Heurkens, 2016)

1.THE HISTORIC BACKGROUND FOR 4TH DIMENSION

Understanding architecture means being able to deal with periods of rigid spatial language, such as the Renaissance and Romanesque. Romanesque architecture was the first phase after the renaissance, when European civilization pushed in harmony towards the renovation of architecture. Romanesque architecture was a totally organic revolution, producing something totally. Two features characterized Romanesque architecture: the integration of all elements of a building; and metrical space. With the first, architecture stopped functioning in terms of surface area and articulated itself in terms of structure. Strategic management focuses away from the skin to the bone skeleton. The slow and incremental concentration of thrusts and resistance; the decrease in wall thickness; the final removal of the triumphal arch that obstructed the church's unity; the absence of the atrium and the consequent increase in focus to the façades, which now reflected the articulation of interior space in two dimensions. The body had become a motivated organism of its wholeness and circulation, and it had started to move. The Romanesque cathedrals of France, England, Spain, and all of Europe, the psychological stimulation that now directed a man's walk, while a building was much more dynamic than just a one-sided declaration of direction, as before. Fig (1) (Youssef, 2015).

The Baroque period was followed by the Neo-Classic period and by 19th century Eclecticism with its numerous revivals. From the point of view of interior space, the 19th century offered variations in taste and new conception. The principal building themes of the late 19th century, and the beginning of the 20th century, represented a total variety in inner space according to the site criteria that allow the designer to innovate. So the shape of the site and the site constraints produced the dynamic form as shown in Edgar Kaufmann house 'Falling water' designed by Frank Lloyd Wright, Fig (2) as a stream runs under the house and the stratified stone walls appear to grow from the landscape as they support cantilevered balconies. It seems that Part of wright's genius was to place the house a top of waterfalls rather than situating it on adjacent ground with views to the falling waters. Wright had set out to break the box

while at work in Oak Park Forty years earlier. In this plan, the service spaces are more enclosed to the rear, while the living spaces in front to break out dramatically onto the landscape. So wright in his design didn't cut time as his design matches the time flow and appreciate it in elevations and plans, he used the dynamic design in plans by designing a small rectangular module represented by the stairs and duplicate it and move by it in an untraditional way to form such convenient plan to the site, also he accepted the presence of the water flow in the elevations which is actually dynamic and used the site row materials but after reshaping the stones which means pass of time to produce refine form of them. (Fox, 2016)



Fig (1): Romanesque Architecture, Italy - S. Ambrogio, Milan, Italy

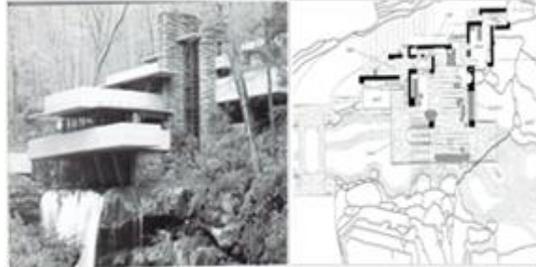


Fig (2): Edgar Kaufmann house 'Falling water' designed by Frank Lloyd Wright

“Source” (Photograph of Basilica of St. Ambrogio, n.d.; Youssef, 2015)

1.THE DYNAMIC ARCHITECTURE (4TH DIMENSION)

Regardless of the design process, Architecture is experienced through the senses, which consequently offers rise to acoustic, visual, smell, and physical architecture. As users move through a space, architecture is considered a time sequence. Despite the fact that architecture is considered to be a visual skill, the other senses have a great role in describing both natural and built environments. Our behaves towards the senses depend on culture.

The design process and the sensory experience of a space are different perspectives, each one has its own language and expectations. (Henderson, 2009)

Mainly the visual sense helps in redefine the techniques of construction which deal with the building forms as “**The 4th Dimension**”. The idea of the fourth dimension in architecture contains three basic roles seem to treat directly with sustainability as follows.

1. The visionary of the building.
2. The static movement of the building. (The geometric access)
3. The kinetic movement of the building.

3. SUSTAINABILITY BY THE 4TH DIMENSION

We can express the relation between the fourth dimension which represent the architecture morphology and sustainability which is the call of the era through three main relations between the building lateral envelope and the environments which are as follows:

3.1 The Visionary of The Building

The move inside and outside – between the building and the urban context is considered to be a 4th dimension feature as it is considered to be a motion no matter what happened with the body or eye. To achieve this movement, the building envelop has to involve certain aspects to achieve transparency. (Premier, 2012)

Unluckily, the modern architecture has used the fully glazed lateral envelop with no windows as the buildings were fitted out with air-conditioning, but the weather in these primary glass buildings was inadequately well known. Shades and thermal insulation appear technical troubles where the glass could not get over at that time producing what is called “sick building syndrome” getting from using air conditioning. So, the result was the need to A new concept for building lateral envelop which tries to attain an intelligent integration of all features of thermal insulation, shading devices, natural lighting, and natural ventilation to a maximum level more than the past. To achieve this, new, special glass types have saved glass a high status as a material. The innovator in these innovations was always architects, who discovered new ways and used the defects to declare new demands.

Recently, the Building envelop plays an important role in such part. It became a screen, pure membrane. However, the exterior skin and its elements have become the essential focus of analysis. As the more technical supplies increase, the more complex challenging and insulation rules gradually become firm, almost every outside skin become a multi-layered structure which its faces hardly give us any vision into the inside life of the building. (ibid.)

To establish the physical presence of a building, one of its elements has to be sustainably low -energy idea such as the outer surface, beginning with simple sliding and folding shutters or with the flexible movable louvers in multi-layered glass lateral envelop fitted out with plenty of manoeuvres for glare and shading protection, light refraction, heat –and energy gain.

Another solution is the outer skin to be made from new sustainable materials as in the Cyber Texture Egg Building (Mumbai, India) figure (3). Designed by James Law, Cyber texture International, and engineer, the “egg” houses 33,000 m² of staff space in 13 levels, attaining this using around 15 percent less area than a conservative building of the same size. The building supports floor without the need for frustrating columns.

Architect James Law created the term ‘Cyber-texture’ to recognize the merger of architecture, ecological design, advanced engineering, and smart systems needed to fulfil user’s needs and create a new urban environment.

The Egg is full of inventions concentrated on ecological sustainability. Its design permits the best use of natural light, producing energy needed that is lower than average. The Egg has photovoltaic panels on its envelop and wind turbines on the top floor, that provides it with another electrical supply and makes itself sustainable. The rooftop is also characterized by an additional element: a natural raised garden that helps cooling the structure, gives oxygen, and provides accommodations to the users who need a rest. The building attains sustainability and energy efficiency through its passive solar design, the inclusion of a raised garden which helps in refreshment of

the interior through thermalization, use of photovoltaic panels and wind turbines on the top roof, and the capability to recycle collage. (Miles, Berens, Eppli, & Weiss, 2015).

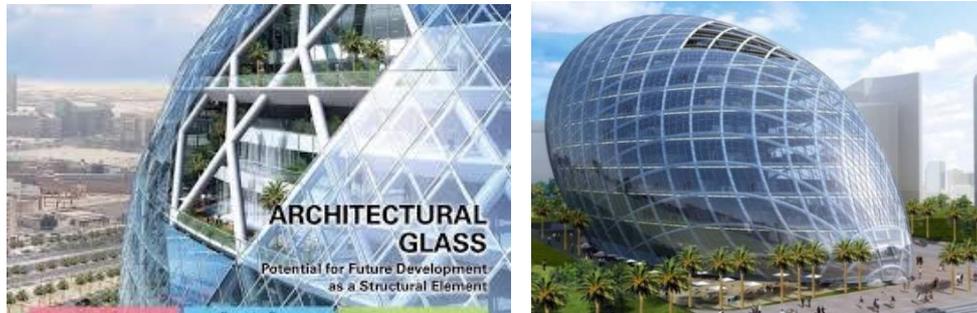


Figure (3): Cyber Texture Egg Building (Mumbai, India)
“Source” (Photograph of Cybertexture Egg, 2021)

3.2 The Static Movement of The Building (The Geometric Access)

The 4th dimension according to visualizing “4d hypercube” connectivity means the transfer of a cube in the direction (to us unimaginable) of the 4th dimension. This movement is extended to a distance equal to one side of the cube and its direction is perpendicular to all our 3-dimensions as each of these 3 is perpendicular to the others. The shape contains an unlimited number of finite 3-spaces (cubes) and is surrounded by 8 cubes, 24 squares, 32 lines and 16 points (vertices). (Chiarella, 2004)

In this way, if the form concerns more than 8 vertices, as this theory deals with the 8 vertices as 3d. The motion of any part of a solid means shaping it and in this concept the mirror seems to reflect the same cube so it causes multi-vertices cube so it may change the 3d to 4d. (Henderson, 2009) Figure (4)

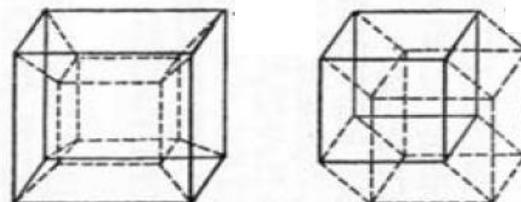


Figure (4): The 4th Dimension
“Source” (CM Article in DesignIssues, 2021)

At the present time, the existence of computer-aided programs within hi-technology that improve the skill of architects, the principles of sustainability have been achieved in most buildings within the 4- dimension in contemporary architecture.

Since the 4th dimension movement happens during the design process, so, we can consider it resulting from the computer-aided programs, or to a definite movement in architecture, as follows:

- Adapting or modifying regular forms.
- Irregular forms (Deconstruction).

3.2.1 Editing or adapting regular forms

Any building in a form of a cube or mainly an eight vertices form; when this shape is modified or edited in form of addition or subtraction or stretched or copied, this could be considered as the 4th dimension application. Figure5 (A, B)

Also, this change could allow the resilience form which propagates within the surrounding nature in a sustainable manner. (Zhang, 2015)

| | | |
|---|---|--|
|  |  |  |
| Subtraction | Copy – Mirror | |
| Circle by AM project China | Dubai towers | Bahrain Financial harbour |

Figure (5 A): Editing and adapting the regular mass of building “Source” (Photograph of Guangzhou Circle by AM Project, 2021)

| | |
|---|--|
|  |  |
| Stretch | Addition |
| Henan Art Centre in Zhengzhou, capital city of Central China's | Crown Plaza Dubai Festival City |

Figure (5 B): Editing and adapting the regular mass of building “source” (Photograph of Henan Art centre, Zhengzhou, 2021)

3.2.2 Irregular forms (Deconstruction)

Deconstruction in architecture, also called De-constructivism, is an improvement of Postmodern Architecture that began in the late 1980s. It is categorized by concepts of disintegration, irregular processes of design, an attention in handling concepts of a lateral envelope or skin, which help in mislead and displace the architecture elements in the lateral envelope. The final visual appearance of buildings that display many deconstructivism "styles" is categorized as a motivating unexpected disorder. (Kınayoğlu, 2007).

De-constructivist buildings, with their illogical designs, may enrich the microclimate in a way developing their unique forms giving them a functional dimension. Using microclimate criteria, Deconstruction forms could enrich the residents’ comfort. De-constructivists have to put into confederation the adaptation of their designs with

climatic state to add value to their thoughts. Figure(6) (Chesbrough & Prencipe, 2008).



Figure (6): Deconstruction forms
 “Source” (Photograph of UFA Cinema Centre, 2021)

3.3 The Kinetic Movement of The Building

The kinetic movement means the actual movement that has been recently seen in the architecture, as it moves totally by itself or partially with the movement of some of its elements.

3.3.1 The partially movement

Architecture can be designed to be modified in certain techniques. Instead of bearing or frustrating uncontrolled changes in buildings caused by ordinary or anthropological effects, some architects are looking for using these effects as a formal component in their designs. Recently, more designs have been done on so called adaptive building facades, which in the best situation, are able to react to their adjacent environments in a way relatively unlike previous structures. Depending on their design, smart systems, and their passive and active components, they have the ability to react reversibly to their environment for a long period of time. This mission needs materials and tools with reversible properties called Changeable materials. (Premier, 2012)

The determining constraints related to architecture that can be designed as changeable parameters include: Shape, Color (appearance), Sound (noise), and Odor (scent). For many reasons, it may be useful for the shape of a part or the whole of a building to have the ability of being changed or changing itself. So called transformable roofs, i.e., folding roofs or with sections that slide over one another, and consisting of rigid or flexible surface. (ibid.)

The Kolding Campus, University of Southern Denmark is an exact green building that automatically opens and closes groups of shades on its southern façade. The “intelligent” system trails the quantity of sunlight entering the windows and takes into account the time of day and season. Also, the building has solar units on its top roof that produce 25 kW of power. (Figure 7) (Yerzhanov, Lapin & Aldakhov, 2019)

The Kolding Campus, University of Southern Denmark Building is an innovative construction embracing recycled things, renewable energy, and solar power, reflecting the University of Newcastle’s guarantee to the surroundings.



Figure (7): kolding campus, university of southern denmark
 “Source” (Photograph of Kolding Campus, University of Southern Denmark , 2021)

3.3.2 The total movement of the building

Buildings today need to be energy efficient and sustainable within their contextual environments. This aim has been fulfilled by means of some applications could be added to the building to gain energy or reduce energy, but lately it has been sounded that the building itself could be the source of energy by its movement as we can see in the twisting design of Cayan Tower of Dubai (figure 8). Designed by Skidmore, Owings and Merrill SOM architectural group. (Wanick, 2019)

The tower was completed by rotating each floor 1.2 degrees around a cylindrical elevator and service core leading to a unique and ever developing structure that introduces a fourth dimension to architecture.

Cayan Tower's apartments are designed with reconstructed wooden floors, Chinese artificial marble counter tops, and kitchen fittings. The tower also contains a five-story parking garage behind it. The Cayan Tower has house bankrolling options available for those users who desire to lease out their weekend or holiday flat. The tower's rooms are designed in such a way that they wouldn't be affected by direct sunlight due to titanium-colored metal panels on pre-casting concrete columns supported with repetitive staggered screen to stop entering sunlight inside the building which disturb the residents of the unit. The lack of balconies helps with the feeling of enclosure and passive solar shading.



Capital tower Abu Dhabi



Cayan Tower, Dubai,

Figure (8): Total movement of the buildings
 “Source”(Photograph of Capital Tower Abu Dhabi , 2021)

The other building is the capital tower of Abu Dhabi, United Arab Emirates designed by RMJM .The building has a (diagonal grid)) specially designed to absorb and control the forces produced by wind and earthquakes loading, as well as the grade of Capital Gate. Capital Gate is one of only a trickle of diagonal grid buildings in the world.

The Capital Gate project could attain its inclination through an engineering system, known as pre-cambering, that allows floor plates to be loaded vertically up to the 12th floor and flabbergasted, one over another, between 300 to 1,400 millimeters. The gravitational pressure caused by the 18° inclination is countered by the Pre-cambering, using a core of reinforced concrete with steel. with the core intentionally built slightly off-center. It is also fixed to the ground by 490 piles which are penetrated 20 to 30 meters underground. (Petersen, 2013).

Capital Gate was designed by architectural company RMJM and was finished in 2011. The tower contains 16,000 square meters of workplace space and a Hotel from 18 floors to 33 floors.

4. RESULTS

- The twentieth century, many attractive designs have focused on the concepts of Time as a way of developing an innovative architecture.
- From the cases described in the paper, we can see that architectural design is often connected to the future. Where time is the key point, the idea that time makes the design more innovative every time the designer makes his design.
- The paper shows that the contemporary architecture is an architecture that could tell its own story and its surroundings.
- The paper aims to re-join with human understanding of time and understanding space by establishing a relationship between them that affects the building innovation and the environment in general.
- Architects can fulfill their interest to put creative forms and designs while respecting the surround environments.
- Human beings don't have a pollution problem; they have a design problem. If humans were to devise products, tools, furniture, homes, factories, and cities more intelligently from the start, they wouldn't even need to think in terms of waste, or contamination, or scarcity. So, Good design would allow for abundance, endless reuse, and pleasure
- The idea of sustainability, or ecological design, is to ensure that our use of presently available resources does not end up having detrimental effects to our collective well-being or making it impossible to obtain resources for other applications in the long run.

5. CONCLUSIONS

- Today the world is threatened by Climatic Changes, the Global Financial Disasters, and main social trials. The technique we design and redesign our buildings makes a change: It can be part of the problem or part of the solution!
- Sustainable design seeks to minimize the negative environmental impact of buildings by efficiency and moderation in the use of materials, energy, development space and the ecosystem at large.

- innovative ideas are necessary. Such ideas in architecture do share to the whole improvement and encourage improvement. Architectural designs are gradually developing techniques and included well-matched elements which widely affect the design forms and shapes.

-The fourth dimension 'Time' become part of architectural design which can, from sensitive usage, improve the sustainability of the built surroundings. Three main features of the 4th dimension can cooperate with surrounding environment resulting in sustainability. These attributes are:

- The transparency of the building.
- The static movement of the building (The geometric access):
 - Editing or adapting the regular forms.
 - Irregular forms. (Deconstruction).
- The kinetic movement of the building:
 - The Partially Movement.
 - The totally movement of the building.

-Novel architectural designs have to be enhanced by careful care to ecological features since it becomes undesirable to deal with architecture individually from its environment. Choice and description of a well-matched element and related component techniques are necessary in the design process.

-The paper looked at the movement of architecture across different documents dealing with the relationship between time, shape, and materials. It has been shown that several factors are involved in the expression of architectural movement. The reasoning behind the methodology proposed for categorizing movement is to concentrate on the sensational movements that are inspired by being present in space. This means that motion in architecture express the time factor

-has played a strong significant role in architectural philosophy as the vital and complicated logical part of architecture.

Table 1: The Effect of Time and Form on Architecture

| | | THE EFFECT OF FORM | | |
|---------------------------------------|----------------------------------|----------------------------|----------------------------------|--|
| | | Level change of form | | Sustainable Effect |
| MAIN FEATURES OF 4TH DIMENSION (TIME) | Visionary of buildings | Outer skin of the building | provides a sheltered environment | eco efficiency |
| | | Inside the building | Sustainable environment | |
| | static movement of the building | regular Forms | subtraction | allow the breathing form which grows within the environment in a sustainable manner. |
| | | | addition | |
| | | | mirror | |
| | | | stretch | |
| | kinetic movement of the building | Irregular forms | Deconstruction | enhance the microclimate standards in a way improving their unique abstract forms giving them a functional dimension |
| | | Partially movement | façade | tracks the amount of sunlight entering the windows-(consume energy) |
| | kinetic movement of the building | totally Movement | The whole body of the building | the building itself could be the source of energy by its movement(consume energy) |

Source: the researcher

*** Recommendations for Future Researches:**

Architects Have to Introduce Future Researches in This Field Which Illustrate the Following.

- What is the relationship between architecture and nature?
- How does the environment affect architecture?
- Flexible architecture can be lifesaving, providing an immediate solution for various styles of buildings. As the idea of flexibility in architecture is often useful.

REFERENCES

Chesbrough, H., & Prencipe, A. (2008). Networks of innovation and modularity: a dynamic perspective. *International Journal of Technology Management*, 42(4), 414-425.

Chiarella Chiarella, M. & Faduunl, A. (2004). *Geometry and Architecture: Nurbs, Design and Construction*. Universidad Nacional del Litoral Facultad de Arquitectura, Diseño y Urbanismo Santa Fe – Argentina.

Moffett, M., Fazio, W. M. & Wodehouse, L. (2009). *A World History of architecture*. Laurence King Publishing. Second edition: Graw- Hill companies, Inc Mc, p (496, 497) London United Kingdom

Fox, M. (Ed.). (2016). *Interactive architecture: adaptive world*. Princeton Architectural Press print edition (ISBN 1568989466).

Henderson, L. D. (2009). The image and imagination of the fourth dimension in twentieth-century art and culture. *Configurations*, 17(1), 131-160.

Karanouh, A., & Kerber, E. (2015). Innovations in dynamic architecture. *Journal of Facade Design and Engineering*, 3(2), 185-221.

Kınayoğlu, G. (2007). *A Reconsideration of the concept of architectural space in the virtual realm*. (Master's thesis). The graduate school of natural and applied sciences of middle east technical university, Çankaya/Ankara, Turkey.

Marques, B., & Loureiro, C. R. (2013). Sustainable architecture: Practices and methods to achieve sustainability in construction. *International Journal of Engineering and Technology*, 5(2), 223-224.

Miles, M. E., Berens, L. G., Eppli, J. M. & Weiss, A. M. (2000). *Real estate development: principles and process*. isbn13: 9780874208252. Published by Urban Land Institute. U.S. Amazon books.

Petersen, S. N. (2013). *Time and Form: Designing in the Fourth Dimension*. (Doctoral dissertation). The Faculty of the Graduate School of the University of Maryland, College Park, United States.

Premier, A. (2012). Dynamic Façades and Smart Technologies For Building Envelope Requalification. In K. Gasparini (Ed.), *Media environment: New technologies and tools for the communication and valorisation of the built environment* (Vol. 1, pp. 65–69). Italy: Knemesi.

Squires, G., & Heurkens, E. (2016). Methods and models for international comparative approaches to real estate development. *Land Use Policy*, 50, 573-581.

Wanick, V. (2019). Beyond 3D: Designing possible futures through the power of the fourth dimension. *Revista Brasileira de Expressão Gráfica*, 2(7), 124-143.

Yerzhanov, S. Y., Lapin, V. A., & Aldakhov, Y. S. (2019). Monitoring the changes of dynamic characteristics of a high-rise building. *Journal of Physics: Conference Series*, 1425(1), 012008. IOP Publishing.

Youssef, W. (2015). *Architecture and the Fourth Dimension*. 10.13140/RG.2.1.3066.0002.

Zhang, X. (2015). Green real estate development in China: State of art and prospect agenda—A review. *Renewable and Sustainable Energy Reviews*, 47, 1-13.

[Photograph of Basilica of St. Ambrogio]. (n.d.). *Basilica of St. Ambrogio: The most important early Christian basilica in Milan* [Photograph]. Retrieved from <https://www.notonlygolf.com/listings/basilicasantambrogio/>

[Photograph of Capital Tower Abu Dhabi]. *Capital Gate / RMJM. (2021): An iconic distinguished tower by a dramatic steel and glass façade* [Photograph]. Retrieved from <https://www.archdaily.com/889854/capital-gate-rmjm>

[Photograph of Cybertecture Egg] Cybertecture Egg. (2021): *The diagrid exoskeleton building which forms a rigid structural system in Mumbai, India* [Photograph]. Retrieved from <http://www.jameslawcybertecture.com/?section=projects&id=1057#prettyPhoto>

[Photograph of Edgar Kaufmann House, Fallingwater]. Artsy. (2021): *An extraordinary house that redefined the relationship between man, architecture, and nature* [Photograph]. Retrieved from <https://www.artsy.net/artwork/frank-lloyd-wright-edgar-kaufmann-house-fallingwater>

[Photograph of Guangzhou Circle by AM Project] as architecture. (2021): *A landmark building located in Guangzhou* [Photograph]. Retrieved from <https://aasarchitecture.com/2014/01/guangzhou-circle-by-am-project.html/>

[Photograph of Henan Art center, Zhengzhou] Kunkel Consulting. (2021): *A hub of the creative arts located in Zhengzhou, China* [Photograph]. Retrieved from https://www.kunkel-consulting.com/ru/projects/2005/05_henan-art-center-zhengzhou

[Photograph of Kolding Campus,] University of Southern Denmark (2021). The facade is an integrated part of the building which create a unique and varying expression [Photograph]. Retrieved from <https://www.archilovers.com/projects/16806/kolding-campus-university-of-southern-denmark.html>

[Photograph of SDU University of Southern Denmark] Campus Kolding. (2021): *A unique and varying Kolding, Kinetic Facade* [Photograph]. Retrieved from <https://www.pinterest.com/pin/158259374383076230/>

[Photograph of UFA Cinema Center] Cinema architecture, Deconstructivism, (2021): *An amazing building conceived as an urban space* [Photograph]. Retrieved from <https://www.pinterest.es/pin/478577897879708092/>