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Vision and Methodology to Support Sustainable Architecture Through Building Technology in the Digital Era

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Abstract

The last decades have witnessed countless, progressive, and rapid advances in the field of building technology, which has a strong impact on the construction industry. Consequently, employing these techniques to support sustainable architecture has become a pivotal issue. Since architecture is a product of the available technology era, building technology could be a contributing factor to reinforce sustainable architecture, where it could promote raising the efficiency of the environmental performance of the architectural product. This paper introduces a methodological framework to support sustainable architecture through building technology in the digital era through an analytical study of the interactions between building technology and sustainable architecture. In addition, this paper analyzes the influence of the technological revolution in the digital era on the axes of building technology (implementation methods, construction systems, construction materials) from the sustainability perspective so as to conserve natural resources for future generations.

Keywords

Building Technology; Sustainable Architecture; Digital Era

1. Introduction

Sustainability is not only an optimal option for our future, but it is also perceived as an essential alternative, therefore, architects need to adopt eco-friendly practices and materials that reduce the impact of the building industry on the environment. Alternative ways to construct buildings are required using green, renewable energy resources as well as technology that entails recycling and reuse. The architectural product is a product of the available technology. Building technology plays a significant role in supporting sustainable architecture, wherein it can contribute to enhancing the efficiency of the environmental performance of the architectural product. Supporting building technology for sustainable architecture has become imperative to preserve the rights of future generations and to conserve natural resources for them as well. Attempts are being made to use building technology to achieve sustainability, but the problem remains in the lack of understanding of how to approach modern techniques in the field of building technology and the solutions that can be offered to achieve sustainable technological architecture. Hence, sustainability and building technology must be used as the basic and important alternatives in architectural design, not as architectural fashion. Thus, the research problem relates to the use of modern building technology in the digital era and the evolution and development in a wide vision in proportion to the environmental conditions to achieve sustainability in its comprehensive concept. In this context, this paper presents the following questions and tries to answer them:

How can building technology support sustainable architecture?

Which axis of building technology can support sustainability to a greater extent?

Accordingly, this paper assumes that the success of sustainable architecture lies in achieving the integration between the sustainability objectives and the available technologies in this era. In addition, it aims to understand the interrelationships between building technology and sustainable architecture. Moreover, it also aims to create a methodological vision to use modern building technology in the era of the digital revolution within the framework of sustainability considerations. Thus, reaching the foundations of a sustainable architectural product that depends on modern building technology techniques and innovating an architectural product that is compatible with the environment to achieve sustainable architecture.

2. Research methodology

This paper deals with an analytical study of the interactions of building technology and sustainable architecture and analyzes the impact of building technology on supporting sustainable architecture. Furthermore, the research presents an analysis of three contemporary projects of the digital revolution era for each axis within building technology and evaluates the success of each axis in achieving sustainability assessment elements. Finally, the evaluation results are used as a guide in selecting appropriate technologies for each standard of the criteria for supporting sustainability which is proposed by the research. Accordingly, these reviews are used to propose a methodological framework that supports environmental sustainability through building technology in the digital era.

3. Basic Concepts: Sustainable Architecture, Building Technology in the Digital Era

Technology: ”science of craft” is the collection of techniques, skills, methods and processes used in the production of goods or services or in the accomplishment of objectives. Technology is a way to solve problems and a way of thinking; it is a mean not a result. Technology is the best procedure to employ resources which are used to achieve human well-being (welfare).

Building technology: Building or construction technology are the tools and techniques, using precise and advanced sciences in the field of building and construction, for the creation of buildings or places for people to escape the natural elements. Moreover, it refers to how to convert buildings into an industrial process including mechanization, administration, employment, production rates and building materials. The field of building technology is divided into three axes which are construction materials, construction systems and implementation methods.

Architectural technology: is architecture that applies available modern technologies in the preparation of designs and models or in the ways and methods of implementation and construction. Another definition is “The ability to analyze, synthesize and evaluate building design factors in order to produce efficient and effective technical design solutions which satisfy performance, production and procurement criteria” (Architectural Technology BSc (Hons), 2012). An example for architectural technology in the digital era is the Walt Disney Concert Hall by architect Frank Gerry who used modern techniques of digital design and operations executively in designing the building and the external coatings, which were designed and implemented using a software that was specially prepared and developed by Frank Gerry’s technology institution, figure 1**.**

Sustainable architecture seeks to minimize the negative environmental impact of buildings by improving efficiency and being moderate in the use of materials, energy, and development space. Sustainable architecture uses a conscious approach to energy and ecological conservation in the design of the built environment (Sustainable

Figure 1. The Walt Disney Concert Hall in L.A.

Architecture and Simulation Modelling). The idea of sustainability, or ecological design, is to ensure that our actions and decisions today do not inhibit the opportunities of future generations (Doerr Architecture, Definition of Sustainability and the Impacts of Buildings). Consequently, sustainable architecture includes the following principles:

– Reduce the consumption of non-renewable resources.

– Beautify the natural environment.

– Remove or reduce the use of toxic materials.

Sustainable buildings can be defined as those buildings that have minimal adverse impacts on the built and natural environment in terms of the buildings themselves, their immediate surroundings and the broader regional and global settings (Liliana Beltrán, Ph. D lecture 1., Environmental Systems). Subsequently, the five objectives for sustainable buildings can be defined as:

Resource efficiency.

– Energy efficiency (including Greenhouse Gas Emissions Reduction).

– Pollution prevention (including Indoor Air Quality and Noise Abatement).

– Harmonization with the environment (including Environmental Assessment).

– Integrated and systematic approaches (including Environmental Management System).

There are other issues which should be considered in order to address sustainable construction. This includes energy efficiency during the construction and post-construction period of a facility. In addition, minimization of greenhouse gas emissions. Also, design and construction of the facility are done in such a way that encourages green transport and water conservation. Moreover, waste minimization and management during the construction and at the time of demolition in addition to the consideration given to the wildlife and local nuisance during the design and construction phases. Hence, these are six basic issues that affect sustainable architecture and sustainable building, figure 2.

Many global institutions that are specialized in the field of environmental sustainability have established standards and ways for assessing and classifying the buildings around the world. Subsequently, the research deals with the LEED "Leadership in Energy and Environmental Design "standard, since it is the most crucial and prominent

Figure 2. Outlinessix issues for the sustainable architecture andsustainable building.

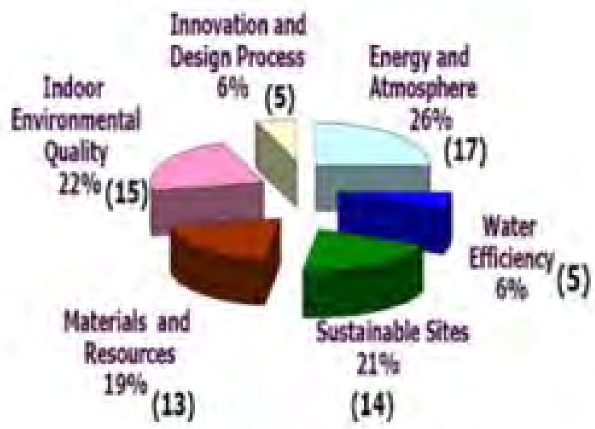

Figure 3. LEEDcategories as % of total points (69).

of these standards. Thus, the certificate of (LEED) is presented to the outstanding projects, (LEED) Includes 69 points divided as follows, see figure 3.

As shown in figure 4, in the search for criteria to evaluate the support of building technology for sustainable architecture, the most important elements can be a guide to creating a research checklist.

Through all of the above, the checklist is divided into eight elements for evaluation, see table 1.

Use of renewable energies. Use of available resources.

Comfortable indoor environment.

Reduce energy and resource consumption. Harmony with the environment.

Reduce costs.

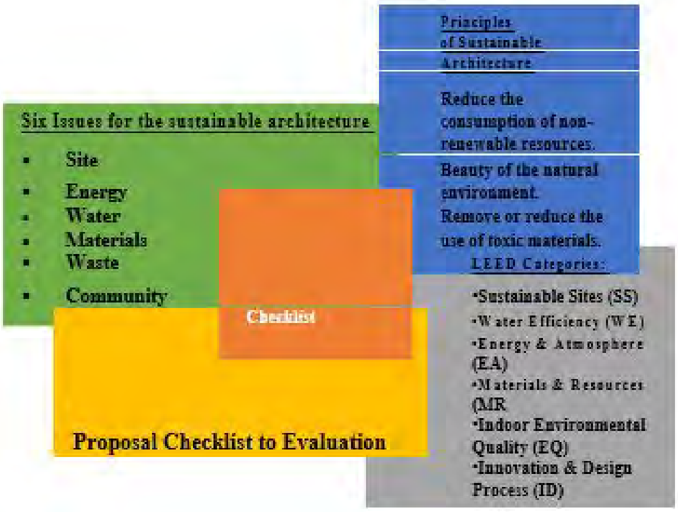

Figure 4. Guide elements for the search about Checklist.

Innovative design. Beautiful design**.**

Table 1. Proposal Checklist to Evaluation

Checklist to evaluate the support of building technology for sustainable architecture		
Project:		
sustainability		
	Found Efficiently	Found
	2 point	1 point
Use of renewable energies		
Use of available resources		
Comfortable indoor environment		
Reduce energy and resource consumption		
Harmony with environment		
Reduce costs		
Innovative Design		
Beautiful design		
		Final score:
		....

4. Building Technology for Supporting sSustainability in the Digital Era

The digital revolution has produced many new terms each of which reflects a new aspect of change that has become abundantly clear in our contemporary lives. These terms include artificial intelligence (AI), digital forms, virtual reality (VR), and cyberspace. Figure 5 illustrates the impact of the digital revolution on architecture.

Eco-Tech is a term that summarizes the relationship between building technology and sustainability. Eco-Tech: is the term given to architecture in the fields of environment and new technologies in architecture. It is nowadays one of the leading fields of architecture in the modern era. The concerns of this field pour into the area of Sustainable Architecture and High Technology. The pioneers of the field are Renzo Piano, Richard Rogers, and Norman Foster. This term symbolizes a shortcut to the two words:

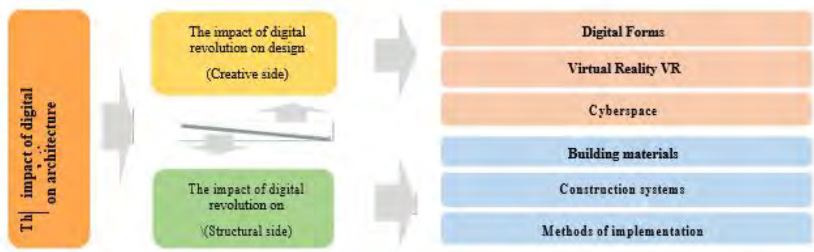

Figure 5. Theimpact of digital revolution on architecture.

Eco=ecology: means the science dealing with the relationships of organisms with their environment and with each other.

Tech=technology: means technology, the best use of the knowledge, resources and adapted to achieve human well-being.

The impact of the technological revolution in the digital era (Structural side):

The influence of the digital revolution has extended to the structural component of architecture in the field of building technology. The fact is that it is noticeably represented in the accelerated development for each of the methods and equipment of implementation or through building materials where computer and technical revolution techniques have been capable of shortening the time required for the implementation of any building in addition to the assistance in the manufacturing process and the implementation of any project. Regardless of how difficult in their composition or their spatial dimension, the following is a presentation of the effects of the technological revolution in the digital era on building technology axes from the sustainability perspective.

4.1. Building Materials in Supporting Sustainability in the Digital Era

The digital revolution has generated a boom in building materials. It has produced many modern and developed building materials, whether basic building materials or complementary building materials. In the digital revolution, the computer plays a major role whether it is a direct role through different softwares or indirectly through manufacturing and testing processes. As shown in figure 6, the methodology of the digital revolution impacts building materials.

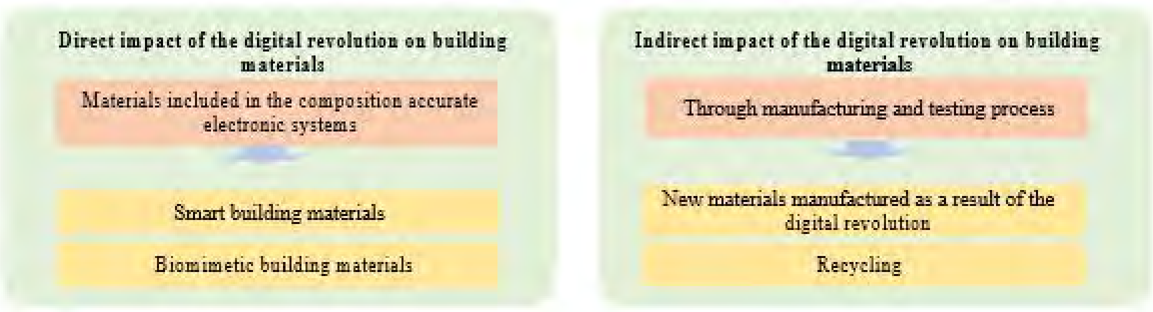

Figure 6. The impact of digitalrevolution on architecture.

Consequently, the development of building materials is regarded as one of the most important axes that should be taken into consideration when considering supporting sustainability. This is because the material used in the construction plays a significant role in determining the type of the required technology for manufacturing and subsequently, the quality and the amount of energy expendable whether in the stage of construction, operation or occupancy. The following are examples of building material of the technical revolution era in the twenty-first century and the extent of its support for the sustainability principles.

4.1.1. **Example 1 for (Building materials): Guggenheim Museum, Prefabricated Facade Systems**

Basic information: The Guggenheim Museum Bilbao designed by architect Frank Gehry is located in Bilbao, Spain. Guggenheim Museum is considered as one of the most impressive works of contemporary architecture because it represents ”one of those rare moments when critics, academics, and the general public were all completely united about something.” (Tyrnauer, 2010). In the 2010 World Architecture Survey that was conducted among architecture experts estimated that the museum was nominated as the most important piece of architecture in the period from 1980 until 2010.

Project description: Frank Gehry used three different elements to form the building façade of the museum. The interconnecting shapes of stone, glass, and titanium unfold on a 32,500-square-meter site along the Nervión River (Muschamp1997), the greatest number of difficulties arose when intersections formed by two or three different materials meeting in peculiar points, see figure 7. Therefore, the exterior cladding of the building that assigns its signature shape was very difficult to design and construct**.** Frank Gehry said in an interview in Harvard Design Magazine that the building was constructed on time and budget, which is rare for the architecture of this type. Subsequently, he elaborated on how he executed it. He added that he used computer visualizations produced by his own digital project software (Ragheb, 2001), (Guggenheim Museum Bilbao).

Supporting sustainability principles through Building materials in The Digital Era

The exterior of the building has a very unusual shape, from plates and irregular forms, which was designed and constructed by prefabricated techniques by the digital revolution. The fact that provided a chance to cut the huge number of pieces of small metal, that are characterized by different forms and dimensions. The computer was programmed to cut all of these needed forms into parts very quickly and free from the constraints of the principle of standardization.

Both CATIA and BOCAD (a steel detailing program) were used in the creation of the building. CATIA significantly upgraded the level of complex forms that could be realized by Frank Gehry. This allowed more freedom in his designs and “simplified construction by providing digital data that could be employed in the manufacturing process, thus controlling costs” (“Frank Gehry, architect, 2001; Ragheb, 2001; “Digital Gehry Material Resistance Digital Construction, 2001).

4.1.2. **Example 2 (Building materials): Cellophane House, Smart Wrap, Facade Pane**

Basic information: Smart wrap appeared at the Cooper Hewitt fair in 2003. Smart wrap is a thin plastic film designed to cover a building as a multi-tasking and intelligent wall. The basic concept for Smart Wrap was refined and advanced through the design of Cellophane House, in 2008, see figure 8 The outer walls of Cellophane House are formed out of seventy-four Smart Wrap panels, each containing photovoltaic film adhered to PET and layers of ultraviolet blocking film (Kieran, 2011).

Project description: The Smart Wrap wall assembly consists of four functioning layers fixed on an aluminum frame. Each wall panel included an outer transparent PET weather barrier, an inner PET layer with thin-film photovoltaic cells, an inner layer of solar heat and UV blocking film, and an interior layer of PET. The sensors on the west facade of the house collected thermal data.

A vented cavity between the PET layers was used to hold heat in the winter and vent it in the summer, reducing the amount of energy required to heat and cool the house.

Supporting Sustainability principles through Building materials in The Digital Era

Casing Material Intelligent (SmartWrap) is a very thin material in fish-based polymer. This film has the ability to change color and appearance. In addition to energy conservation, it also improves the indoor climate, lighting, and electricity. Based formulations of this smart cover do not require traditional windows to allow light to enter. This is due to the ability to form windows and places that could be easily modified by controlling the degree of transparency of the atmosphere (Robert, 2007).

Figure 7. Guggenheim Museum
Source (Bilbao, Guggenheim Museum Bilbao)

Smartwrap has revolutionized the building industry because this material includes all the regular wall functionality such as insulation, protection, electricity, and windows. However, it is compressed into a material that is only a few millimetres thick. Moreover, the features of intelligent cover Smartwrap include:

The ability to change the color and appearance. Lightweight.

Internal climate control and lighting. Execution speed and high quality.

can be transported and installed very quickly.

provides insulation, passive ventilation, UV protection, and renewable energy. easily disassembled and fed into a recycling stream.

4.1.3. **Example 3(Building materials): Jubilee Church,** nanotechnology

Basic information: The Jubilee Church was designed by architect Richard Meier, figure 9. Jubilee Church is a landmark when it comes to the use of nanotechnology in building materials. Jubilee Church was constructed in 2003 and its white concrete shows no signs of darkening even years later. Its white color is still as bright as the day it was constructed (Halford, 2011).

Project description: Jubilee Church walls contain titanium dioxide particles to keep the appearance of the church white. Under the influence of (UV)-light and water (humidity), nanoscale titanium dioxide quickens chemical reactions, this is process that breaks down and decomposes organic material. This process, known as photocatalysis, is applied to the construction industry and architecture to create “self-cleaning” building materials and to break down air pollutants (Nanotechnology in construction, 2012).

Supporting sustainability principles through building materials in the digital era

Nanotechnology increases the building performance, energy efficiency, environmental sensing, and sustainability,

Figure 8. Cellophane House, Smart Wrap, Facade Pane
Source (Kieran, 2011).

UV protection, corrosion resistance and waterproofing.

Nanotechnology removes and renders benign pollutants from a building's surrounding atmosphere (intersecting of nanotechnology materials for green buildings).

It is predicted that Nanotechnology offers many environmental performance benefits including improvements in solar insulation and coatings, advances in water, air infiltration and solar technology.

4.2. Construction Systems in Supporting Sustainability

The technological revolution has brought a boom in construction methods. The fact that facilitates the possibility of creating any blocks, no matter how seemingly impossible the implementation and design of the façades with their vertical and horizontal sections may be. It was impossible to imagine the complex designs through a simulation software and three-dimensional modelling. Additionally, it now calculates the expected loads, external influences such as wind, earthquakes, and hurricanes according to the nature of the environment in which the building would be built. Accordingly, all the above support sustainability principles in terms of saving time and energy. The following figure shows the impact of the technological revolution system on construction systems from the sustainability perspective, figure 10.

Figure 9. TheJubilee Church built with photo-catalytically active, “self-cleaning”

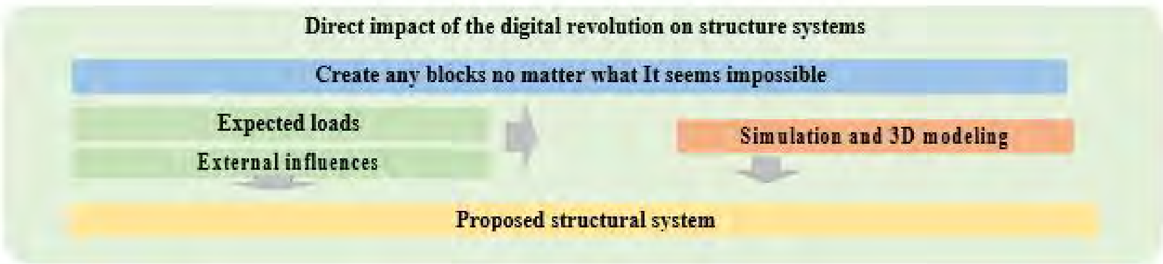

Figure 10. Direct impact ofdigital revolution on structural systems

4.2.1. **Example 1 (Construction systems): Water Cube National Swimming Centre**

Basic information: The Beijing National Aquatics Center, also officially known as the National Aquatics Center and colloquially known as the Water Cube, is an aquatic center that was built alongside Beijing National Stadium in the Olympic Green for the swimming competitions of the 2008 Summer Olympics, see figure11. Despite its nickname, the building is not an actual cube, but a cuboid (Beijing Cubism, ETFE Revolutionized the Bubble). **Project description:** The idea of the project is based on soap bubbles. The architects emulated the random appearance of clinging soap bubbles with each other by making organized models taking the form of cells with 12 through 14 facets. The project consists of 100,000 m of ETFE bubbles. The fluoropolymer is a plastic material which has several advantages:

It weighs one-tenth of glass.

It is more flexible and transparent.

It allows passing a larger amount of light.

It is an excellent insulator, so it saves more than 50% of lighting costs.

Supporting Sustainability Principles:

Simulating the form and clinging bubbles with each other enriched the architectural form of the building which bestowed aesthetic values.

The up-to-date technology and computer technology, which was used in manufacturing and cutting ETFE did not waste time, manufacture costs, or materials. They could cut 3500 pads to fit their place well, and they had to make just one pad.

Simulation bubbles’ transparent appearance with the use of the transparent ETFE with its advantages saved the costs of lightning and helped with the rationalization of energy.

Figure 11. Watercube National Swimming Centre structure system, interior.

4.2.2. **Example 2 (Construction systems): Bird's Nest Stadium in China**

Basic information: The Swiss office "Her Zog et De Mevron" developed the Bird's Nest Stadium together with the Chinese government in 2008 in Beijing China.

Project description: The stadium was given this name because the iron bars are similar to a bird's nest. It was designed by simulating birds' shelters which consist of organic material such as branches and grass. The structure of the bird's nest is innovated on the grounds of structural systems and the way of how to distribute loads. Designers of the bird's nest used DP. Digital Project (DP) is a 3D Building Information Modelling (BIM) system which uses CATIA as a core engine and also used the simulation technique (CFD) so as to simulate temperatures, wind power, and humidity inside the structure of birds' nests in addition to giving the audience the opportunity to enjoy light, see figure 12.

Supporting Sustainability Principles:

The use of simulation in designing the bird's nest is to develop a strong structural system.

Unique architectural formation has aesthetic values. Moreover, the simulating natural ventilation and the lighting systems help to rationalize energy. This, in turn, helps in reducing operating costs.

It also reduces pollution emitted from the building as a result of the rationalization of energy consumption.

4.2.3. **Example 3 (Construction systems): Swiss Re Headquarters**

Basic information: Swiss Re Headquarters, designed by Foster and Partners, is remarkably similar in its structure to the skeleton of a sea creature known as a "glass sponge." London, 1997 - 2004**.**

Project description: Using a series of geometric shapes on the exterior similar to those of a glass sponge makes the structure stiff enough to resist structural loads without extra reinforcements. In the same way that the glass sponge takes in nutrients from the water by sucking water from its base and expelling it through the holes its top, the building ventilates air in a similar fashion, see figure 13**.**

Supporting sustainability principles:

Figure 12. Bird'sNest Stadium n China, exterior.

Figure 13. (Swiss Re Headquarters) under construction

The tower's window opens for natural ventilation and is backed by spiraling light wells; these features were designed to cut energy consumption by half thus, reducing the impact of industrial air conditioners on the environment.

The new structure, which is inspired by the glass sponge, gave the durability and flexibility of the structure and the beauty of the design (A gherkin to suit all tastes, magazine features).

4.3. Implementation Methods for Supporting Sustainability

Building technology has conceded at a myriad phase throughout the ages. Consequently, Building Production Technology can be divided into three phases. Firstly, the period of dependence on the muscle strength of man. Secondly, the period of using machines as helping tools. And finally, the period of full replacement of machines instead of human forces. Accordingly, with the advent of the digital revolution, the techniques used in the implementation process have evolved. For instance, manufacturing processes, supervision, follow-up implementation and the use of automated construction equipment that are remotely controlled. This equipment are remote-controlled both in the drilling equipment, lifting, or even to transfer and install where the equipment is supplied by softwares including site data, speed, weights and wind each implementation. Moreover, remote-control of location variables and ensuring that no obstacles or collision occurs and avoiding all risks. As a result, all the above support sustainability principles from being cost-effective to educing time-consumption as well as increasing the quality of the architectural product. On the other hand, Fourth Dimension 4D applications also appeared and are considered as a creative, strong surge in implementation. It means adding the fourth dimension (time element), which helps to analyze the implementation timeline that leads to avoiding difficulties or problems that may arise during the implementation process, figure 14.

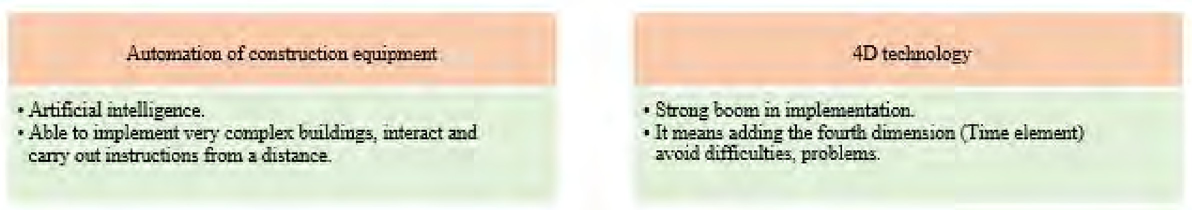

Figure 14. ImplementationMethods in supporting sustainability. Sourcebythe researcher.

4D Technology: 4D simulation software is capable of generating visualizations which illustrate construction processes along the timeline. In order to create a 4D simulation, a three-dimensional BIM model is required, followed by the time-consuming task to link 3D objects of a building to the tasks in a time schedule, which helps to reduce errors. 4D simulation can improve communication among project members and help to avoid planning failures. The 4D simulation system consists of four distinct parts: (1) 3D model of a building, (2) Time schedule, (3) 4D simulation, (4) Productivity modification. (Building Information Modeling BIM, 2016;

Interactive 4D-CAD; Kathleen, 2012; Enhancement of availability of 4D simulation based on Building Information Model technology).

Automation of construction equipment is characterized by artificial intelligence where it can implement very complex buildings, interact, and carry out instructions from a distance and install building components precisely and quickly. Furthermore, the automation of production blocks, standards, and the prefabrication of various building components may lead to converting the design of buildings into a process of selecting parts. These techniques have also led to reducing the cost, the time of execution of major projects, and energy efficiency. Figure 15 shows the multi-functional building unit used to raise and enter the components of prefabricated houses into a supporting structure. However, these standard components have a multi-variable distribution to allow for maximum individual expression in interior design and decoration.

4.3.1. **Example 1(Implementation Methods): Phoenix International Media Center**

Basic information: Phoenix International Media Center is in Beijing and designed by the Beijing Institute for Architecture Design (BIAD) with Shao Weiping. Phoenix International Media Center is a steel torus of a structure enclosed with 3,800 glass panels, each differently sized and detailed see, figure 16. This project puts 3D digital design into practice (Giovannini, 2014).

Figure 15. Multi-function unit. Source (Fresco, 2007)

Figure 16. Phoenix InternationalMedia Center. Source (”Phoenix International Media Center”, 2011)

Project description: The Phoenix International Media Center is the first locally design-built parametric project by Chinese architects and engineers. The building area is 65,000 square meters and the building has a height of 55 meters. The techniques that are used in the project are an integration of BIM and parametric design processes in the workflow. Moreover, the techniques used for fixing the axes and a series of loops, in the plan, from which they generated the geometry for the surface of the torus. The complexity of the building’s latticed façade with its differently stretched web of steel implies the complexities of parametric modeling, wherefore, the project represents an up-to-date approach to design and building. Shao says that the latest 3D modeling software enables the architects to conceive and execute the project, which requires a high degree of precision (Weiping, 2012; Zewo, 2012). Other features of the design are the steel ribs which channel water into a collection tank that will then be filtered and distributed into the surrounding water features and landscapes. Additionally, the double skin facade will reduce energy consumption and maintain comfortable temperatures within the building in the winter and summer.

Supporting Sustainability Principles:

- In spite of the complexity of the building's latticed façade and the complexities of parametric modeling,
- the project was implemented without wasting time or costs due to the integration of BIM and parametric design processes.

4.3.2. **Example 2 (Implementation Methods): The Yas Viceroy Abu Dhabi Hotel**

Basic information: The Yas Viceroy Abu Dhabi Hotel is known as one of the icons of Abu Dhabi, UAE. It was designed by Hani Rashid and Lise Anne Couture. The project was initiated as one of the most rapid projects in performance and incompatibility with the schedule as much as possible -440 days from concept design to the opening day of the Grand Prix. No schedule delays were possible (The big picture: The Yas Hotel, 2009; The Yas Hotel / Asymptote, 2009).

Project description: The hotel consists of two twelve store hotel towers, one placed in the Marina and another set within the race circuit. They are linked together by a monocoque steel and glass bridge and Grid Shell structure that both crosses above and over the Yas Marina Circuit F1 race track. Many of the automation and optimization processes were developed by Gehry Technologies (GT) for detailed design of the Gridshell, allowing for a constantly updateable process where changes in design were rapidly populated to full construction details. GT staff was able to rapidly populate the digital model with all of the temporary structures that would be required throughout the construction phase. Moreover, spatial issues and safety concerns for workers in the areas were analyzed in the model which were most congested with temporary structures, figure 17. Otherwise, by working closely with the contractors and workers, steel fabricators and installers, each of the 172 "ladders" that executed the Grid shell, were incorporated into the building information model and embedded with the necessary data to allow the instantaneous extraction of important information including construction sequences, welding sequences, coordinates of attachment points, and lighting installation data and glass panel (Gehry Technologies Yas Viceroy Abu Dhabi Hotel).

Supporting sustainability principles:

- The designers and implementers succeeded in achieving their goal of opening the building by the specified time of the race within 440 days from idea to implementation by using BIM techniques.
- Avoid any difficulties during implementation such as increased equipment and temporary installations by incorporating the digital model into the implementation schedule.

4.3.3. **Example 3 (Implementation Methods): Galaxy Soho**

Basic information: Galaxy Soho, Beijing is a 330 000m2 office, retail, and entertainment complex, designed by Zaha Hadid. The 330,000 sqm mixed-use develop covers 18 floors, three of which are underground and the offices occupying levels four to fifteen.

Project description: The project is composed of five independent concrete volumes wrapped in insulated aluminum panels and linked by a series of stretched bridges. These volumes are adapted to each other in all directions, generating a panoramic architecture without corners or abrupt transitions (Galaxy-Soho). Non-traditional facades and the use of glass, steel, and composites in new structural ways requires unique techniques and special methodologies, see figure 18. This has been achieved using many techniques that were used in the Galaxy Soho project including (DP, BIM). Digital Project is a 3D Building Information Modelling (BIM) system developed by Gehry Technologies, which uses CATIA as the primary engine. Zaha Hadid said about using BIM system "We explore a range of solutions from the primary gesture through the use of digital tools within the overall creative process. On projects of this scale and complexity, accuracy is as crucial as flexibility and speed, as the 3D data is a critical component of project execution." (Zaha Hadid Architects Develops Visionary Buildings with Software from Dassault Systèmes Partner Gehry Technologies, 2009).

Figure 17. The Yas Viceroy Abu Dhabi Hotel.

Figure 18. Galaxy Soho. Zaha Hadid: Soho Galaxy in Process, design boom

Supportin g sustainability principles:

- Accuracy, speed of implementation and no matter how complex configuration is being realized through the availability of the high fidelity digital 3D information that DP provides.

5. Evaluate the support of building technology for sustainable architecture

It has been analyzed how the success of Building Technology axes in The Digital Era in supporting Sustainable Architecture through some of the architectural projects that were designed based on the Building Technology in

The Digital Era. The first axis is Building materials, the second axis is the Construction systems, the third axis is the Methods of implementation. The following is a compilation of data that have been extracted from the analysis of each project. In order to reach the best technologies that support sustainability, the best techniques that achieve rationalization in the consumption of energies and resources, and help to achieve aesthetic values. The best technologies that support innovation in design in addition to reducing costs, either construction or maintenance cost. As well as many important results as a guide to the efficient utilization of building technology axes, see table 2, figure 19.

Table 2.Checklist to evaluate the support of building technology for sustainable architecture

Checklist to evaluate the support of building technology for sustainable architecture

Project:	Building materials				Construction systems				Methods of implementation			
Sustainability	Project1 Guggenheim Museum	Project2 Cellophane House	Project3 Jubilee Church	Building materials final score:	Project1 Water Cube National Swimming	Project2 Bird's Nest Stadium	Project3 Swiss Re Headquarters	Construction systems final score:	Project1 Phoenix International Media	Project2 The Yas Viceroy Abu Dhabi Hotel	Project3 Galaxy Soho	Methods of implementation final score:
Use of renewable energies				2				3				0
Use of available resources				1				0				0
Comfortable indoor environment				4				3				0
Reduce energy and resource consumption				6				3				3
Harmony with environment				2				3				1
Site Safety				0				0				6
Reduce costs				3				1				3
Innovative Design				5				6				5
Beautiful design				4				6				6
final score:	8	9	10	27	8	8	9	25	8	8	8	24

6. Conclusion

The above analysis demonstrates the superiority of the Building materials. In addition, it elaborates that most of the projects which have used these techniques were able to reap the highest points to support sustainability.

Most of the projects in this evaluation have shown significance in these two elements "Innovative Design and Beautiful design". Hence, projects that have employed the techniques of building technology in The Digital Era have an innovative design and high aesthetic values.

The use of digital techniques in implementation methods has helped to a great extent to achieve the site safety precautions.

The use of digital techniques in building materials has assisted in reducing energy and resource consumption.

The use of digital technologies in building technology axes (building materials, construction systems) has facilitated achieving a comfortable internal environment, and the implementation methods have not affected attaining a comfortable environment for users.

The use of digital techniques in implementation methods has helped to decrease the implementation costs and the use of building materials influenced by the digital revolution which has led to reducing the operating costs.

The results show that the first axis of building technology gets the highest points in support of sustainability with a simple difference with the other axes. The fact which confirms that the conscious use of modern techniques can aid to support sustainability

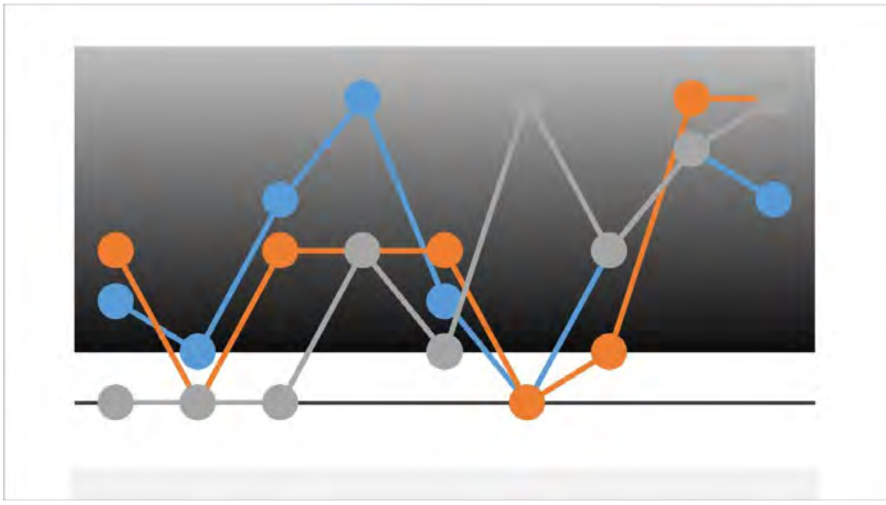

Figure 19. The result of the evaluation.Source:Researcher

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