International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 9 Issue 1, Jan-Feb 2025 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Emerging Technologies in Architecture

Matthew N. O. Sadiku[1], Paul A. Adekunte[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]International Institute of Professional Security, Lagos, Nigeria
[3]Juliana King University, Houston, TX, USA

ABSTRACT

Modern architecture is characterized by freedom of ideas mainly due to the development and implementation of new technologies for architects. In our digital age, countless architectural innovation technologies are emerging and changing the way we design. Emerging technologies enable architects to implement ideas with greater precision and efficiency, reduce environmental impact, and create more sustainable and functional buildings. Emerging technologies are not just enhancing efficiency and precision; they are reshaping the very way we conceive, design, and construct the built environment. These exciting technologies drive the future of architecture and engineering. The primary objective of this paper is to comprehensively investigate the challenges and potentials of the adoption of emerging technologies in modern architecture.

KEYWORDS: *technology, emerging technologies, architecture*

How to cite this paper: Matthew N. O. Sadiku | Paul A. Adekunte | Janet O. Sadiku "Emerging Technologies in Architecture" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-9 | Issue-1, February 2025, pp.213-223, URL: www.ijtsrd.com/papers/ijtsrd73840.pdf

IJTSRD73840

INTRODUCTION

Technology has become a powerful enabler. It has long reshaped the possibilities of architecture. When we talk about technology, we often think of robots, supercomputers, data centers or smartphones. But technology also refers to the invention of the first chipped stone tools. Technology is nothing more than the application of knowledge to achieve goals in a specific and reproducible way, for practical purposes. Technology is altering not just the architecture industry but the role of an architect. In the digital world, builders have seen technology as a means to optimize practices and identify, build, and manage their projects. Without new technologies, designers would not be able to accommodate the more complicated demands of the industry. Technology in architecture is depicted in Figure 1 [1].

Digitalization in the architecture, engineering, and construction (AEC) sector is slow due to significant challenges in technology adoption. Although transforming the AEC sector with digital technologies (such as building information modelling (BIM), artificial intelligence (AI), cloud computing, big data, blockchain, virtual reality (VR)), new knowledge about technology implementations can help research and practice. The rapid evolution of digital technologies has brought forth an era of constant change and innovation.

Now, new digital design tools are transforming how buildings are made. New digital tools have empowered architects and designers, stretching the boundaries of physics and imagination while providing the required complex calculations and visualizations. The structural ideas that underpinned skyscrapers, mosques, cathedrals, and temples evolved using increasingly sophisticated computers and digital modeling tools,

The architecture, engineering and construction (AEC) industry is at the forefront of a technological revolution that will redefine how we design, build, and experience the built environment. As technology continues to rapidly advance, architects need to stay ahead of the curve and incorporate cutting-edge tools into their design processes. Technological integration has revolutionized the field of architecture, enabling architects to create more sustainable, efficient, and innovative buildings that meet the needs of modern

society. It has transformed the field of architecture, enabling architects to create more sustainable, efficient, and innovative buildings. Figure 2 shows a building under construction [2], while Figure 3 displays some construction workers [3].

WHAT ARE EMERGING TECHNOLOGIES?

Technology may be regarded as a collection of systems designed to perform some function. It can help alleviate some of the challenges facing business today. Emerging technology is a term generally used to describe new technology. The term often refers to technologies currently developing or expected to be available within the next five to ten years. Any imminent, but not fully realized, technological innovations will have some impact on the status quo.

Emerging technologies are shaping our societies. They continue to affect the way we live, work, and interact with one another. Emerging technology (ET) lacks a consensus on what classifies them as "emergent." It is a relative term because one may see a technology as emerging and others may not see it the same way. It is a term that is often used to describe a new technology. A technology is still emerging if it is not yet a "must-have" [4]. An emerging technology is the one that holds the promise of creating a new economic engine and is trans-industrial. ET is used in different areas such as media, healthcare, business, science, education, or defense.

The characteristics of emerging technologies include the following [5]:

- *Novelty:* Emerging technologies are typically new or novel, meaning they have yet to be widely adopted or used. They often represent a significant departure from existing technologies or processes.
- *Potential for Disruption:* Emerging technologies have the potential to disrupt existing markets, industries, or ways of doing things. They may also displace existing businesses or industries.
- *Uncertainty:* Because emerging technologies are still in the early stages of development, there is often a high uncertainty surrounding their future potential and impact. It can be challenging to predict how they will evolve.
- *Rapid Change:* Emerging technologies often evolve rapidly, with new developments and innovations emerging frequently. It can make keeping up with the latest trends and advancements challenging.
- *Interdisciplinary*: Emerging technologies often involve multiple disciplines or fields of study, such as computer science, engineering, and biology. They may require collaboration across different fields and industries to develop their potential fully.

Emerging technologies are worth investigating. They are responsible for developing new products or devices. As emerging technologies continue to evolve, engineering is poised for a transformative future. Emerging technologies have driven innovation and progress in today's rapidly evolving digital landscape. The collective impact of emerging technologies such as artificial intelligence, machine learning, big data, and the Internet of things is undeniably transformative. Some emerging technologies are shown in Figure 4 [6].

EMERGING TECHNOLOGIES IN ARCITECTURE

The AEC sector is known for its traditional methods and slow adoption of technological advancements and innovations. In spite of this, architecture has always progressed as advances in technology and creativity push each other forward. Architectural history cycles through technological breakthroughs and explosions of creativity, with new tools and building techniques leading to a flowering of new forms. Emerging technologies are reshaping how businesses operate, innovate, and compete. Popular emerging technologies in architecture includes the following [7-9]:

1. *Building Information Modeling* (BIM): BIM is a cornerstone in AEC. It is a digital method for creating and managing detailed 3D models of buildings, including data about their parts and systems, for construction, design, and maintenance purposes. It advances the digital transformation of the AEC industry by enabling data-driven, end-to-end asset lifecycle management. BIM software has become an essential tool for architects, allowing them to create detailed digital models of buildings and structures. It lets architects capture real-world locations and landscapes and create 3D digital plans. It thus allows the work of several roles like engineers, architects, estimators, clients, and many others in a single shared process. BIM software improves project planning, scheduling, and material management, improving productivity and cost savings. Revit, ArchiCad, and Allpaln are some of the most renowned BIM-compatible softwares. Engineers, designers, and architects can use a BIM program to ensure their specific plans are in alignment before any cutting or welding takes place. Figure 5 shows different components of BIM [8].

2. *Artificial Intelligence* (AI): AI automates tasks such as researching design and code databases, design optimization, site selection, and construction management to save time. AI has started replacing much of the manual work and increasing optimization by efficiently considering all respects from weather and site conditions to experiencing virtual walkways. AI enhances the design process by analyzing factors like structural integrity, energy efficiency, material durability, and cost parameters. What is the most sustainable, material-light way to design this roof? What is the best apartment interior layout, based on thousands of previous designs? What is the right price or bid for construction materials? That is the current reality for architects and engineers, thanks to advances in artificial intelligence (AI) and machine learning, which can take oversize data sets and, with the right prompt, find efficient design solutions. These powerful logic models can take the seed of an idea and create a garden of possibilities. Engineers and architects leverage synthetic or generative AI to generate multiple design iterations that fit the client's specifications and design vocabulary.

3. *Robotics:* A robot is a machine or device programmed to perform tasks autonomously or semi-autonomously, often imitating human actions or functions. Robotics improves the productivity and efficiency of projects by automating tasks such as fabrication, assembly, and construction. Advanced designs rests on precision construction down to the millimeter. A new generation of construction robots promises that level of accuracy and sophistication, often using laser scanners and GPS systems. Robots can perform standard design tasks, such as making models, much faster than humans. It is no sooner that more robots and humans will work together to build a project with greater efficiency. Architectural robots perform dangerous or hazardous tasks such as working at heights or confined spaces. They address the shortage of skilled labor force and improve construction site safety. Autonomous ground-based robots, including four-legged robots, are now capable of successfully navigating complex and typically cluttered construction sites. Figure 6 shows a typical robot [8].

4. *Drones:* Drones and UAV technologies are closely intertwined with robots and robotics, both experiencing a significant increase in interest lately as part of efforts to automate construction sites, capture geometries, detect damages. Drones, a staple in modern construction, will continue to evolve as indispensable tools for surveying and monitoring construction sites. Equipped with advanced sensors, drones will provide real-time data on project progress, site conditions and potential safety hazards. The main help of drones is fixing an object on all sides and at different heights to develop ideal 3D models. But here are more advantages of using them.

5. *Big Data:* Big data is definitely the big thing. It refers to the large volume of data that is being collected and processed by businesses and organizations. It has created waves in architecture in various ways. The vast volume of data that is collected and analyzed by design models can inform future building designs, aiding smart city initiatives that can improve the efficiency and sustainability of entire neighborhoods. With the greater availability of data and the Internet of things, architects are able to access more data that helps them in designing unique and more efficient buildings. Big data could be used to create "smart buildings" that are able to collect and analyze data about their inhabitants.

6. *Generative Design:* This is an emerging trend in architecture that uses artificial intelligence (AI) and machine learning algorithms to generate multiple design options based on a set of parameters. Generative design mimics how organisms function in nature. It is based on algorithms that produce a number of design variations. With generative design, the work of design actually functions like evolution but is much more rapid. Generative design can help architects reduce material usage, improve structural performance, and create unique aesthetic forms. By entering constraints and goals into a script, architects can tap generative design to rapidly iterate solutions, quickly sorting through possible paths to find the right one. Dubai's Office of the Future was constructed in just 17 days, using 3D printing. Canadian startup Maket AI provides a generative AI-powered platform to create schematic designs for building floor plans. It takes environmental and other space constraints in natural language and generates various design variations. Figure 7 shows a typical design [2].

7. *3D Printing:* It is no longer a secret that 3D printing (or additive manufacturing) has gained particular popularity among designers and architects. Creating a traditional model is time-consuming, labor-intensive, and unreasonably expensive. 3D printing is the accumulation of

layers of a certain material –which can be concrete, plastic, metal, earth, and more. Additive manufacturing or 3D printing empowers architects to create unique structures that are difficult to achieve with traditional construction methods. 3D printing is a process that creates three-dimensional objects by adding material layer by layer, based on a digital model. Using 3D printing technology for architecture allows designers to invent and apply completely new and effective aesthetic forms. 3D printing technology makes it possible to reduce work completion time and improve quality. 3D printing and bonding has led to a new generation of machines that can print everything from models to entire buildings. The upsides to these massive printers are myriad, from lower material costs and less waste to dramatically faster and safer builds. 3D printing has not only enabled the building of prototype models of actual structures, but now this technology can build whole of a structure by itself. 3D printing is used to produce materials for constructing buildings, furniture, and interior details. Startups develop 3D printers that support a wide range of materials, including concrete, plastic, and recyclable materials tailored for the architectural sector. Figure 8 shows a building construction using 3D printing [10].

8. *Internet of Things*: The Internet of things (IoT) is a term that refers to the connection of physical objects to the internet. This can be done in a variety of ways, such as through sensors, RFID tags, or QR codes. The purpose of the IoT is to enable objects to communicate with each other and with people. A growing body of sensors, controls, and measurement tools has reshaped building operations; this suite of smart building devices is variously categorized as the Internet of things (IoT). IoT is an advanced technology for architects that links, monitors, and regulates data about the projecting object. Its main task is to competently transfer physical objects into digital ones, constantly monitoring and collecting information about these objects using sensors for data exchange.

9. *Cloud Computing:* The cloud is an online service that allows you to use all systems remotely. Cloud technology refers to the use of remote servers accessed through the Internet to store, manage, and process data and applications. Today, cloud computing is a popular new technology in architecture. Solutions hosted on remote cloud servers enable architects, designers, and contractors to collaborate on projects in real time. This improves communication, reduces errors, and increases efficiency. Changing the architecture of data storage changes the way architects can access data. Remote data storage via cloud computing means that designs, digital twins, collaborative platforms, and simulations can all be hosted and shared with numerous design teams for rapid development and iteration.

10. *Immersive Technologies:* Immersive experiences allow designers, clients, and stakeholders to visualize and experience architectural designs. Architects leverage immersive technologies such as AR, VR, MR, and XR. Although classic 3D models are good at visualization, they provide a different effect than virtual and augmented reality. Designers can use virtual reality to simulate walk-throughs in the real world. VR in architecture allows one to consider how a particular solution will look with the project's other components. It allows architects to better explain their ideas and concepts to their clients in a real-life-like experience. Augmented reality adds to the real-life experience by overlaying 2D over 3D. AR layers digital images on real-world visuals, helping architects, engineers, and construction workers "see" plans applied directly to a construction site. It can also be used to conduct inspections or train workers on new building tools. Unlike virtual reality (VR), AR technology does not require connecting headsets, glasses, or other equipment. All you need is a device camera and an app with AR functionality. Mixed Reality on the other hand allows the interaction between physical spaces and virtual spaces giving rise to concepts like vertical cities due to rapid urbanization. Extended reality (XR)—the umbrella term for both concepts, as well as mixed reality (MR)—allows ease of collaboration and communication despite physical distance. Figure 9 shows a typical use of VR [11].

11. *Blockchain:* Blockchain is a technology that has the potential to revolutionize the way we build. It is a distributed database that allows for secure, transparent, and tamper-proof transactions. Blockchain technology's decentralized and tamper-proof nature will bring a new level of trust and efficiency to the AEC sector. With blockchain, architects would be able to track every stage of the construction process, from design to completion. Blockchain can provide end-to-end visibility into supply chains, ensuring that products are sourced, manufactured, and delivered transparently.

12. *Architectural Apps*: Architectural apps like Revit, Grasshopper, and Rhino are being adapted by various firms worldwide and there is no stopping in more advanced versions of the existing ones or the launching of newer ones with services that are tremendously needed and are time-saving and organized.
13. *Advanced Materials:* Brick, stone, timber, and steel were the main building materials utilized until the turn of the twentieth century. Engineered materials that utilize fewer resources offer better workability over conventional materials are desirable by the AEC industry. These sustainable materials feature high durability, thermal insulation, recyclability, and endurance to withstand high loads and extreme weather. They reduce the environmental impacts of construction without compromising structural performance.

BENEFITS

The primary job of any design or architectural company is to make high-quality architectural models. In an era defined by rapid technological advancement, the architecture and engineering fields are undergoing transformative changes. Cloud computing and generative design enable faster prototyping. Robotics and 3D printing can rapidly assemble structures. Smart monitors and big data analysis can measure building performance and inform the next big design innovation. These digital aids allow human designers to generate and test new ideas. Technologies such as artificial intelligence (AI), virtual reality (VR), 3D printing, and cloud computing improve project quality, coordination, and implementation. Other benefits include the following [9]:

- *Visualization:* Visuals have come a long way from the days of hand-drawn sketches. The transition to digital platforms changed how architects create, communicate, and collaborate. Advances in visualization tools have made it easier to view and communicate projects with compelling depth and richness. Architects can quickly assess the impact of natural and artificial light, materials, and environmental factors on their proposals so that they can make more informed design decisions.
- *Automation:* At the intersection of design, engineering, and science, architectural technology seeks to automate and augment the design process to quicken construction, support management, and ensure high-performance of materials, systems, and structures. Artificial intelligence has the ability to automate tedious tasks, streamline operations, and enhance customer service.
- *Sustainable Design:* Sustainable and climate-positive architecture remains the top priority of the industry. Sustainable urban planning and building design is one area where new methodologies and materials could drastically reduce the carbon footprints of new projects. Technology has made it easier for architects to design sustainable buildings that minimize environmental impact. Sustainability is a driving force behind technological innovations in the AEC industry. The fundamental principles behind sustainable buildings include reducing resource consumption (energy and water efficiency), maximizing the use of renewable or recyclable resources, protecting the natural environment, and creating a healthy environment for users.
- *Renewable Architecture*: The demand for green architecture and high energy costs drive the integration of renewable energy sources in building design and construction. Architects and interior designers utilize renewables-based architecture to improve indoor air quality and natural ventilation through green roofs, biophilic design elements, etc.
- *Circular Architecture:* The architecture industry is adopting the circular economy to design and construct workflows that improve resource efficiency. Innovative circular supply chain platforms enable green construction material sourcing and increase supply chain transparency. These platforms improve regulatory compliance and incentivize greener initiatives.
- *Energy-Efficient Architecture:* Energy efficiency solutions in buildings and structures eliminate heat and energy loss as well as reduce energy and maintenance costs. This significantly curtails maintenance costs while also retaining comfort for occupants. Architecture software for energy-efficient solutions promotes passive design strategies and provides building energy simulations to improve natural lighting and building ventilation.
- *Smart Buildings:* A smart building is a structure equipped with technology and sensors that enable automated control of various systems, such as lighting, and heating. It is equipped with sensors and IoT devices that continuously collect data on energy consumption, occupancy patterns, and structural health. The Internet of things (IoT) has enabled architects to design smart buildings that are connected, intelligent, and responsive to occupants' needs. Smart buildings use sensors, algorithms, and automation systems to optimize energy consumption, air quality, and security.

Technologies facilitating green building design, energy optimization, and material recycling will take center stage as the industry embraces its role in creating environmentally conscious structures.

- *Smart Homes:* These are revolutionizing the way we live now with energy-efficient systems and AI-assisted living. As populations grow and resources become more unavailable, the efficient use of limited resources becomes a necessity.
- *Smart City:* A smart city is an urban area that uses technology and data-driven solutions to improve infrastructure, services, and quality of life for its residents, while promoting sustainability and efficient resource management. Smart cities are a key factor in the consumption of resources. Urban development based on sustainability with a greater focus on renewable energy, transportation solutions, smart home energy management, and public service access are the advances that need to be realized in city technology. A typical smart city is shown in Figure 10 [2].

CHALLENGES

The construction industry has notoriously been slow to adapt to the wave of digitization spreading across various fields. The AEC sector is currently facing significant challenges and opportunities due to technological advancements. Despite the increasing interest in emerging technologies, their implementation often necessitates acquiring specific skill sets. Research indicates a noticeable gap between industry and academia in the adoption and adaptation of emerging technologies. Although emerging technologies offer immense potential for product-based companies, their successful integration requires careful planning and strategic alignment with enterprise architecture. Other challenges of emerging technologies in architecture include the following:

- *Collaboration:* Collaboration is key in architectural design, and technology has made it easier for architects to work together and share information. Cloud-based platforms enable team members to access and edit files from anywhere, promoting seamless communication and coordination. As AEC projects become increasingly global, collaboration platforms tailored to the industry will significantly advance. Architects from different parts of the world will be able to collaborate on projects using cloud-based platforms that allows them to work on the same design simultaneously. Collaboration between academia, research, and industry is crucial.
- *Education and Training:* To fully embrace technological integration, architects must invest in education and training. Professional organizations like the American Institute of Architects (AIA) offer courses in BIM, VR, and sustainable design. They provide accessible and affordable ways for architects to learn new skills and stay up-to-date with the latest technologies. Academia bears a great responsibility to remain at the forefront of the developments and educating tomorrow's AEC practitioners and researchers.
- *Aging Workforce:* The workforce in the construction sector is aging, an increase in project demand and complexity are growing, and employee productivity is falling. Even as reluctance and uncertainty plague the industry, a digital push is intensifying.

CONCLUSION

The architecture industry rapidly adopts new technologies to make smart buildings. New architecture technologies help design the buildings of tomorrow, today. They empower architects to spend more time exploring, creating, and pushing the boundaries of design.

They are going to reshape the future state of application architecture and will help build faster, more secure, scalable, highly available, and innovative products for different business domains. The power of these tools has only begun to be harnessed.

Whether it is more affordable housing or ultra-modern vertical cities, architects are turning to new technologies to help them design the structures of the future. Today's developing technologies will no doubt reshape architecture and design, freeing up mental capacity to solve more complex challenges and create truly human-centered solutions. Emerging technologies increasingly influence architects' work, acting as catalysts for creativity, productivity, and communication. The integration of AI, AR, VR, BIM, robotics, blockchain, and global collaboration platforms will usher in an era where creativity meets efficiency. Exploring these emerging technologies provides valuable insights into the future direction of digital technologies in the AEC sector. More information about emerging technologies in architecture can be found in the books [12-15] and a related journal: *Automation in Construction.*

REFERENCES

[1] "8 Major technology advancements altering architecture," August 15, 2022, https://www.designblendz.com/blog/the-power-of-technology-in-architecture-today

[2] "Emerging technology trends that will help shape future of architecture," https://www.re-

thinkingthefuture.com/designing-for-typologies/a3990-emerging-technology-trends-that-will-help-shape-future-of-architecture/#google_vignette

[3] "What is architectural technology? How innovation is changing the industry," https://www.archdaily.com/1000647/what-is-architectural-technology-how-technology-is-changing-the-industry#:~:text=Architectural%20technology%20is%20a%20vast,artificial%20intelligence%20dominate%20the%20discipline.

[4] M. Halaweh, "Emerging technology: What is it?" *Journal of Technology Management & Innovation*, vol. 8, no. 3, 2013, pp. 108-115.

[5] N. Duggal, "Top 18 new technology trends for 2023," July 2023, https://www.simplilearn.com/top-technology-trends-and-jobs-article

[6] "How enterprise architects integrate emerging technologies to enhance architecture," https://www.linkedin.com/pulse/how-enterprise-architects-integrate-emerging-technologies-qdgfe/

[7] "How new architecture technologies help design the buildings of tomorrow, today," https://www.autodesk.com/design-make/articles/technology-architecture

[8] "Architecture technologies: 9 Recent technological advancements in architecture that architects must know," https://www.re-thinkingthefuture.com/rtf-fresh-perspectives/a1034-9-recent-technological-advancements-in-architecture-that-architects-must-know/#google_vignette

[9] "Discover the top 10 architecture trends in 2023," https://www.startus-insights.com/innovators-guide/architecture-trends/

[10] "How new technologies are evolving to embrace sustainability in architecture," https://www.archdaily.com/991739/how-new-technologies-are-evolving-to-embrace-sustainability-in-architecture

[11] "10 Architectural innovative technologies all architects should know," https://www.arch2o.com/10-architectural-innovative-technologies/#google_vignette

[12] A. Ippolito, *Handbook of Research on Emerging Technologies for Architectural and Archaeological Heritage (Advances in Religious and Cultural Studies).* Information Science Reference, 2016.

[13] W. Quan, *Emerging Networking Architecture and Technologies: First International Conference, ICENAT 2022, Shenzhen, China, November 15–17, 2022, Proceedings (Communications in Computer and Information Science).* Springer, 2023.

[14] G. Sebestyen and C. Pollington, *New Architecture and Technology.* Taylor & Francis, 2007.

[15] Y. Xie (ed.), *Emerging Memory Technologies: Design, Architecture, and Applications.* New York: Springer, 2013.

Figure 1 Technology in architecture [1].

Figure 2 A building under construction [2].

Figure 3 Some construction workers [3]

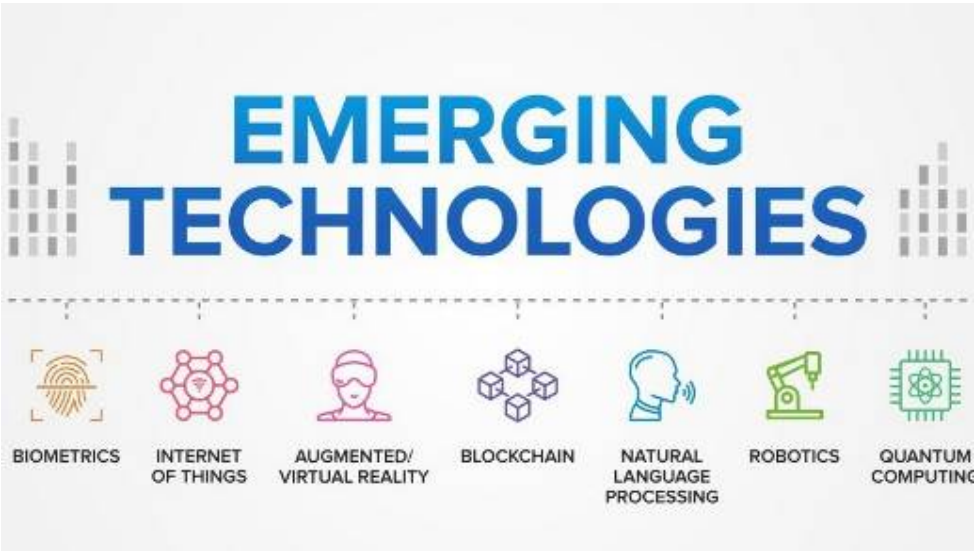

Figure 4 Some emerging technologies [6].

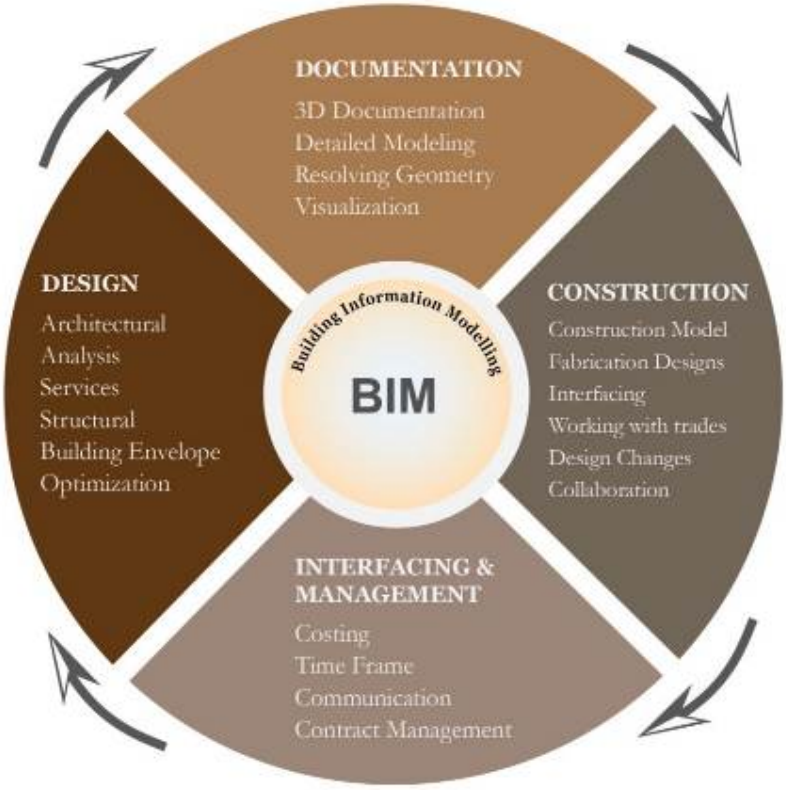

Figure 5 Different components of BIM [8].

Figure 6 A typical robot [8].

Figure 7 A typical design [2].

Figure 8 A building construction using 3D printing [10].

Figure 9 A typical use of VR [11].

Figure 10 A typical smart city [2].