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Cloud Computing in Architecture

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Abstract:

Cloud computing (CC) is the delivery of computing services, such as servers, storage, databases, networking, software, analytics, and intelligence, over the Internet. It is no longer a business trend. It is a new reality in the global market. The power of cloud computing lies in the fact that it is available anywhere, in any size or configuration, and can be easily reconfigured when needed. Using this kind of decentralized system offers flexibility, scalability, and accessibility for architectural teams all around the globe. Cloud computing is emerging as the cornerstone of a new era in architecture; it transcends conventional boundaries and unleashes unparalleled possibilities in the field. It can synchronize architectural projects from concept to construction. Migrating to the cloud enables architects to store, manage, and process their data online. This paper explores ways cloud computing helps organizations in the architecture industry become more efficient, sustainable, and innovative.

Keywords: technology, cloud computing, architecture industry.

INTRODUCTION

Architecture is the art/science of creating solutions that maps to business needs. The architecture, engineering, and construction (AEC) sector is a highly fragmented, data intensive, project based industry, involving a number of very different professions and organizations. Systems and standards are continually evolving in the realm of AEC and often serve as the catalyst for innovation. Cloud computing is the newest technology that delivers computing services over the web. It allows users to access and use resources on demand, without having to invest in or maintain physical infrastructure. It also allows users to access additional storage, enhanced processing power, and hardware-heavy architecture software all remotely through the Internet. Moreover, the architecture

industry is under increasing pressure to deliver high-quality projects in shorter timeframes, leaving no room for human error. Cloud platforms allow architects to fix mistakes quickly. Architects utilize cloud computing primarily to streamline their design process by enabling faster rendering of 3D models, real-time collaboration on projects, and storing large design files on remote servers, all while reducing the need for expensive local hardware and software licenses.

Although cloud computing (CC) is nearly ubiquitous on a personal level, for architecture companies, its adoption has been much slower. This can be attributed to the fact that an architectural project usually involves synchronizing the efforts of many professionals and the level of organization needed is much more sophisticated. The last few years have seen a massive shift in architects adopting digital capabilities from local servers to cloud computing. Cloud computing is turning out to be the connective tissue for more and more modern architectural teams.

Architects are increasingly using cloud computing to access and manage design software, collaborate on projects in real-time with team members across different locations, store large design files, and perform computationally intensive tasks like 3D rendering, all through a centralized online platform, significantly enhancing efficiency and collaboration within their workflow. Architects today are starting to use the cloud for more than just file sharing and storage [1]. Figure 1 shows an architects at work [2].

CLOUD COMPUTING BASICS

Cloud computing represents a newly emerging service-oriented computing technology. It is the provision of scalable computing resources as a service over the Internet. It allows manufacturers to use many forms of new p systems such as 3D printing, high performance computing (HPC), industrial Internet of things (110T), and industrial robots. It is transforming virtually every facet of modern manufacturing. It is innovating, reducing cost, and bolstering the competitiveness of American manufacturing [3].

The key characteristic of cloud computing is the virtualization of computing resources and services. Cloud computing is implemented in one of three major formats: software as a service (SAAS), platform as a service (PAAS), or infrastructure as a service (IAAS). These services are illustrated in Figure 2 [4] and explained as follows:

SaaS: This is a software delivery model in which software and associated data are hosted on the cloud. In this model, cloud service providers offer on-demand access to computing resources such as virtual machines and cloud storage. Nowadays oil & gas companies transition to cloud computing and implement SaaS solutions for operations.

PaaS allows the end-user to create a software solution using tools or libraries from the platform service provider. In this model, cloud service providers deliver computing platforms such as programming and execution.

In the laaS model, cloud service providers can rent manufacturing equipment such as 3D printers.

Just like cloud computing, CM services can be categorized into three major deployment models (public, private, and hybrid clouds) [5]:

- Private cloud refers to a centralized management effort in which manufacturing services are shared within one company' or its subsidiaries. A private cloud is often used exclusively by one organization, possibly with multiple business units.
- Public cloud realizes the key concept of sharing services with the general public. Public clouds are commonly implemented through data centers operated by providers such as Amazon, Google, IBM, and Microsoft.

- Hybrid cloud that spans multiple configurations. and is a composed of two or more clouds (private, community or public), offering the benefits of multiple deployment modes.

These models are shown in Figure 3 [6]. Cloud computing finds application in almost every field.

CLOUD COMPUTING IN ARCHITECTURE

Any firm of architects requires several fundamental tools and technologies to support productivity. Traditionally, computing for architects was almost entirely on-premises. All hardware was in the office, and software ran locally on in-office workstations. It was not too long ago when architects made the shift from manual drafting tables to digital canvases in the form of CAD. Today, one of the newest technological developments is cloud computing. With the emergence of cloud computing in the last 15 years, the way many industries work has been transformed [7].

In architecture, cloud computing refers to the design and implementation of a system where computing resources like servers, storage, and networking are delivered as a service over the Internet. This allows users to access and utilize these resources on-demand without managing the underlying infrastructure.

Shifting from traditional to cloud-based workflows requires a strategic approach. Choosing a cloud provider is of paramount importance. Architects need to consider factors like the service's reliability, security protocols, and integration capabilities. Picking the right service that aligns with specific architectural requirements establishes the groundwork for a smooth and successful transition to the cloud. For a small firm, the clear advantage is that a cloud computing subscription is much cheaper than running their own servers.

Cloud computing can significantly advance your career in architecture by enabling you to design more innovative and efficient buildings, collaborate seamlessly with remote teams, access powerful computational tools for complex analysis, manage large datasets efficiently, and showcase your designs through immersive virtual reality experiences. You do all this while staying at the forefront of technological advancements in the field. The best architects in cloud computing tend to be adept at most of what the platform has to offer. Figure 4 shows some cloud architects [2]. Much like an architect who designs buildings, a cloud architect designs virtual environments and infrastructures. A cloud architect is essentially an IT professional who designs, builds, and manages a company's cloud infrastructure.

APPLICATIONS OF CLOUD COMPTING IN ARCHITECTURE

Cloud computing is providing compute power and other related software services on rent. In architecture, cloud computing is primarily used for collaboration, data sharing, data storage and analysis, project management tools, BIM (building information modeling) integration, visualization tools, and disaster recovery. CC enables architects to access and share large design files, collaborate remotely, and leverage data analytics for better decision-making throughout the design and construction process. Common examples applications of cloud computing in architecture include the following [8,9]:

- *BIM Integration*: Cloud platforms can integrate with BIM software, allowing architects to upload and share BIM models for analysis, coordination, and clash detection with project stakeholders. This involves storing and managing large BIM models on a cloud platform for collaborative design and analysis across teams. Cloud-based BIM software allows architects to store and access large project models from anywhere, facilitating better project coordination and data sharing. Storing and managing large BIM models on cloud platforms allows multiple team members to access and collaborate on design details simultaneously, facilitating real-time updates and coordination. Cloud storage services like Amazon S3 or Microsoft Azure Blob Storage enable efficient storage and access to large BIM models, facilitating easier collaboration and project version control. Figure 5 shows various components of BIM [10].

- *Design Visualization:* The majority of an architect's work revolves around producing documents, while renderings and drawings are the bread and butter of their work. Cloud-based rendering services provide high-quality visualization capabilities, enabling architects to create realistic 3D renderings and virtual tours quickly. Cloud-based platforms with advanced analytics capabilities can be used to analyze large datasets related to building performance, energy consumption, and environmental impact, providing valuable insights for design optimization. Utilizing cloud-based rendering services to produce high-quality visualizations and animations quickly, even for complex models, without requiring expensive local rendering hardware. Cloud-based rendering services allow architects to generate high-quality renderings and visualizations quickly, without requiring expensive hardware, facilitating better client presentations. Cloud platforms offer high-performance computing power for rendering complex 3D models significantly faster, allowing architects to create high-quality visuals with minimal wait time.
- *Collaboration:* Cloud-based design software enables multiple team members to work on the same project simultaneously, making real-time collaboration and design feedback easier, regardless of location, facilitating real-time collaboration on design models and drawings. It allows storing project documents like drawings, specifications, and reports on a cloud platform for easy access and real-time updates by all team members. Its decentralized nature eliminates the need for teams to be in the same physical office to function. Having access to this type of seamless teamwork and remote access enables real-time collaboration and allows teams scattered around the globe to contribute to a project as if they were working in the same room.
- *Remote Access:* Before remote work became common, architects usually kept their project data on computers in their offices. While this could manage 3D models well, documents and spreadsheets can be better handled by cloud storage. Cloud computing allows teams to access and work on project information remotely. Architects and designers can access project files from anywhere with an internet connection, enabling remote work and collaboration. In architectural design, cloud computing allows architects to utilize remote servers to access powerful processing capabilities for tasks like 3D modeling, rendering, design collaboration, and data storage. This results in faster design iterations, improved efficiency, and easier client communication, all while minimizing the need for expensive local hardware. Working remotely means that less time waste, resource waste, and carbon emissions are unnecessarily consumed by commuting to and from the office.
- *Data Analysis:* Cloud computing can be used to run complex simulations like energy modeling, structural analysis, and daylight studies on large datasets to optimize designs. Cloud-based analytics tools can process large datasets related to site conditions, energy usage, and building performance, helping architects make data-driven design decisions. They allow accessing powerful cloud computing resources to run complex energy simulations, structural analysis, and other design calculations.
- *Project Management:* This involves utilizing cloud-based project management platforms to track tasks, deadlines, budgets, and team communication across the project lifecycle. Cloud-based project management platforms like Asana or Trello can be used to streamline project workflows, track tasks, manage timelines, and communicate with team members effectively.
- *Disaster Recovery:* Cloud storage provides a reliable backup solution for critical design data, ensuring that projects are protected against data loss in case of hardware failures or natural disasters. Cloud storage and backup services provide a reliable way to safeguard critical design data against hardware failure or other disasters.
- *Construction Site:* Perhaps the biggest challenge of a building project is that the people who designed it are almost always located away from where it is being built. Even if a project is in

their city, travel back and forth to the site is a huge time commitment for an architect. Unscheduled visits are often made to resolve single issues that require nothing more than designers seeing what the builder is talking about. An upside to using cloud computing in building projects is that the level of integration of CC allows a project team to develop their own custom tools. A typical construction site is shown in Figure 6 [9].

BENEFITS

There are plenty of advantages gained by architects using CC. Cloud computing offers many advantages for architects, such as enhanced collaboration, increased efficiency, improved creativity, and greater innovation. Cloud computing tools are convenient, flexible, scalable, and cost-efficient. They suit any business type and size, from tiny agencies with a few workers to huge international enterprises. The benefits of enhanced collaboration, scalability, and digital security paint a compelling picture of the future of architectural design. Cloud computing is now sophisticated enough to synchronize architectural projects from concept to construction. Other benefits of using cloud computing in architecture include the following [8]:

- *Improved Collaboration*: CC enables real-time collaboration on projects across geographically dispersed teams. Teams from different locations can work on the same project simultaneously. Collaborative design teams, dispersed globally, seamlessly can work on a project using cloud-based tools. Cloud-based design software like BIM (building information modeling) platforms allow multiple architects and stakeholders to work on the same project simultaneously, making real-time edits and accessing the latest design updates from anywhere with an Internet connection.
- *Cost Reduction:* Using cloud-based applications reduces rent and premises costs. CC eliminates the need for expensive high-end hardware and software licenses by leveraging cloud-based resources on a pay-per-use model. By utilizing cloud services, architects can avoid high upfront costs associated with powerful hardware and software licenses. One pays only for the resources used. Cloud computing allows architects to scale their computing resources as needed, reducing the need to invest in expensive hardware upfront.
- *Accessibility:* CC provides access to design data from any device with an Internet connection. Architects can access project data from anywhere with an internet connection. Redundancy allows ensuring continuous access to data and services.
- *Efficiency:* Using the cloud may significantly boost a company's efficiency. Faster rendering times, real-time collaboration, and easy access to design tools can significantly improve design workflow. Faster rendering, collaborative design, and streamlined workflows lead to improved project timelines and productivity.
- *Scalability:* CC allows for easy scaling of storage and computing power as project needs change. Accessing computing power based on project demands allows for efficient resource allocation. It is easy to scale computing resources up or down based on demand. Architects can easily scale up computing power based on project needs, eliminating the need to invest in expensive hardware upgrades.
- *Flexibility:* There is access resources from anywhere with an Internet connection. Cloud computing provides architects the flexibility to adapt to project sizes and building typologies dynamically. Evolving projects can have the resources allotted to them be easily scaled up or down.
- *Data Security:* Cloud providers offer robust security features to protect sensitive design data. In the digital realm, ensuring security is essential. This is doubly important for architecture offices and the files they handle for their different projects. Cloud computing solutions excel in this

regard, in how they implement advanced encryption, authentication protocols, and stringent access controls.

- *Sustainability:* The eco-friendly facets of digital architecture enabled by cloud solutions lie in how it decentralized the architectural design office. Exploring how cloud computing technologies contribute to sustainable practices will inevitably help in aligning the architectural industry with a commitment to environmental responsibility.
- *Faster Rendering:* Cloud platforms provide high-performance computing power to render complex 3D models significantly quicker than on local machines, saving time and allowing for more design iterations.
- *Visualization:* Clients can easily view and interact with 3D models through web browsers without needing specialized software installed on their computers, facilitating better communication and feedback loops.
- *Data Storage:* Cloud storage services provide a secure and scalable way to store large design files, project documents, and backups, eliminating concerns about local storage limitations. Cloud storage services like Amazon S3 or Azure Blob Storage enable architects to store and access massive amounts of design data (including 3D models, point clouds, and images) from anywhere, eliminating the need for large local storage systems. With cloud platforms, architects can organize large amounts of data with flexible storage options that do not affect budgets.
- *Complex Simulations:* Access to high-performance computing in the cloud enables architects to run computationally intensive simulations like energy modeling, structural analysis, and daylighting studies.
- *Design Competitions:* Cloud-based platforms can be used to host online design competitions, allowing architects to easily share their proposals with clients and reviewers globally.

CHALLENGES

There are a couple of common challenges for cloud-based and remote computing among architects. Architects work on very large files. If architects need to edit them remotely, any lag or delay can be very frustrating. An architect needs to develop certain skills to take advantage of cloud computing, such as cloud fundamentals, cloud platforms, cloud applications, and cloud development. Continuous learning and staying updated with industry trends are essential in this dynamic field. Other challenges include the following [11]:

- *Security:* Working in the cloud enhances data security because it reduces the chances of accidental data loss or hacking of on-premise devices. A hacker is shown in Figure 7 [12]. Data breaches can have significant financial and reputational costs. So architects should consider moving to cloud platforms whenever possible. Technologies such as Google Drive and DropBox are often used informally and in an ad-hoc way between individuals, but concerns over security and the protection of intellectual property often dissuade major companies from adopting such services.
- *Culture:* There is a significant cultural barrier to using the cloud in architecture, engineering, and construction. A lot of the consultants and architects are still working using AutoCAD. People are reluctant to change.
- *Transitioning to the Cloud:* Shifting from traditional to cloud-based workflows requires a strategic approach. People resist change. A step-by-step transition plan ensures a smooth integration, minimizing disruptions and maximizing the benefits of cloud computing. Architects can gradually migrate projects, ensuring a seamless evolution in their design processes.

- *Training:* The biggest skill you can have in the cloud space is willingness to learn. Providing architectural teams with essential skills is crucial for success. This is especially true with transitioning to a relatively new technology such as cloud computing which requires a new set of skills and know-how to navigate through. Learning or training on cloud computing can be done in a variety of ways. For example, you can take online courses, such as Coursera.
- *Emerging Technologies:* The future holds plenty of potential in emerging technologies in architecture that can further be integrated into architectural cloud computing. For example, there is continually evolving realm of artificial intelligence for architecture, which automates parametric design programs. The answer to being prepared for any challenges in the field lies in mastering these new technologies.
- *Democratizing Design Work:* This involves using design platforms in the cloud where everyone can see drawings and collaborate on them. This "democratizes" architectural practice. It means firms no longer must rely on a hierarchical approach where one person knows everything, and other employees cannot participate in the creative process.
- *Interoperability:* Projects carried out within AEC sector involve collaboration between various people, using a variety of different systems. This, along with the industry's strong data sharing and processing requirements, means that the management of building data is complex and challenging.
- *Data Management:* Data management the architecture industry can often be fragmented with a lack of an overall data management policy. Data sets relating to a particular project can often be stored in local computers of designers/architects, often with limited network connectivity, persistence, and availability.
- *Data Processing:* This is also an important concern for the architecture industry. During construction, a large proportion of work takes place on construction sites where computing resources are limited. Allowing users to make changes on a portable device on site that can then be processed remotely leading to the plans on site being updated is extremely desirable.
- *Governance of BIM Data:* BIM allows a building to be modelled across its entire life-cycle, from concept design to construction. Cloud computing capability would make most sense when utilized alongside a BIM data representation. However, due to the complex project based nature of the AEC industry, any data stored in a cloud system would need to be heavily managed. This level of management is essential to ensure that the data is able to meet the legal and contractual requirements for each individual project and to also ensure that the intellectual property rights.
- *Storage:* One of the key issues within the industry is the storage of building data during design/construction and over the entire life of the building. Several companies have developed servers for the storage of building data.

CONCLUSION

Cloud computing is still an emerging technology within the AEC sector. The architecture industry has struggled to keep up with the trend. However, cloud platforms have become widespread in recent years with the increase of remote working. From increased access and data protection to better collaboration and rendering time, the cloud has revolutionized how architects work [13].

In a field that evolves at the speed of innovation, architects must stay ahead of the curve. Cloud computing has the potential to become the basis for plenty of potentially industry-changing developments. The universal call to utilize cloud technologies to their full potential reverberates throughout the architecture and design community. Architects seeking to embark on this transformative journey must elevate their design workflows, amplify collaboration, and embrace the future of architecture with confidence. Cloud-based computing for architects is here to stay. More

information about cloud computing in architecture can be found in the books in [14-17] and the following related journal: *Journal of Cloud Computing.*

REFERENCES

1. B. Libby, “Designing in a cloud: How architects are using cloud-based programs to deliver the best projects,” December 2014,

   https://www.architectmagazine.com/practice/best-practices/designing-in-a-cloud-how-architects-are-using-cloud-based-programs-to-deliver-the-best-projects_o

2. “Cloud architect role: What is a cloud architect,” Unknown Source.
3. S. Ezell and B. Swanson, “How cloud computing enables modern manufacturing,” June 2017,

   https ://itif.org/publications/2017/06/22/how-cloud-computing-enables-modernmanufacturing

4. “Cloud computing applications in agriculture,” .https://www.eescorporation.com/cloud-computing-applications-in-agriculture/
5. "Cloud manufacturing," *Wikipedia*, the free encyclopedia https://en.wikipedia.org/wiki/€loud_manufacturing
6. S. Saini et al., "[Retracted] cloud computing: Legal issues and provision," *Security and Communication Networks*, vol. 2022,

   https://www.hi dawi.com/jo rnals/scn/2()22/2288961/

7. D. Rekko, “Cloud-based computing for architects is already here,” June 2024,

   https://www.designair.io/blogs/read-more/cloud-based-computing-for-architects-is-already-here

8. A. Centino, “How architecture offices can leverage cloud computers,” December 2023,

   https://vagon.io/blog/how-architecture-offices-can-leverage-cloud

9. R. Brady, “How architects can supercharge their project workflow using the cloud,”

   https://architizer.com/blog/practice/tools/architects-cloud-computing/

10. “What is BIM,”

    https://bimmda.com/en/what-is-bim

11. T. H. Beach, “Cloud computing for the architecture, engineering & construction sector: Requirements, prototype & experience,” *Journal of Cloud Computing*, vol. 2, no. 8, 2013.
12. “You’re looking to advance your career in architecture. How can cloud computing help you get there?”

    https://www.linkedin.com/advice/3/youre-looking-advance-your-career-architecture-sq8wc

13. A. Murtagh, “Cloud computing for architects: How to increase efficiency,” December 2022,

    https://www.rock.co.uk/insights/cloud-computing-architects-how-increase-efficiency/

14. M. N. O. Sadiku, *Cloud Computing and Its Applications*. Moldova, Europe: Lambert Academic Publishing, 2024.
15. B. Furht and A. Escalante, *Handbook of Cloud Computing.* New York: Springer Science Business Media, 2010.
16. T. Erl and E. Monoy, *Cloud Computing: Concepts, Technology, Security, and Architecture.* Pearson, 2nd edition, 2023.

17. G. Reese, *Cloud Application Architectures: Building Applications and Infrastructure in the Cloud.* O'Reilly Media, 2009.

Figure 1. An architects at work [2].

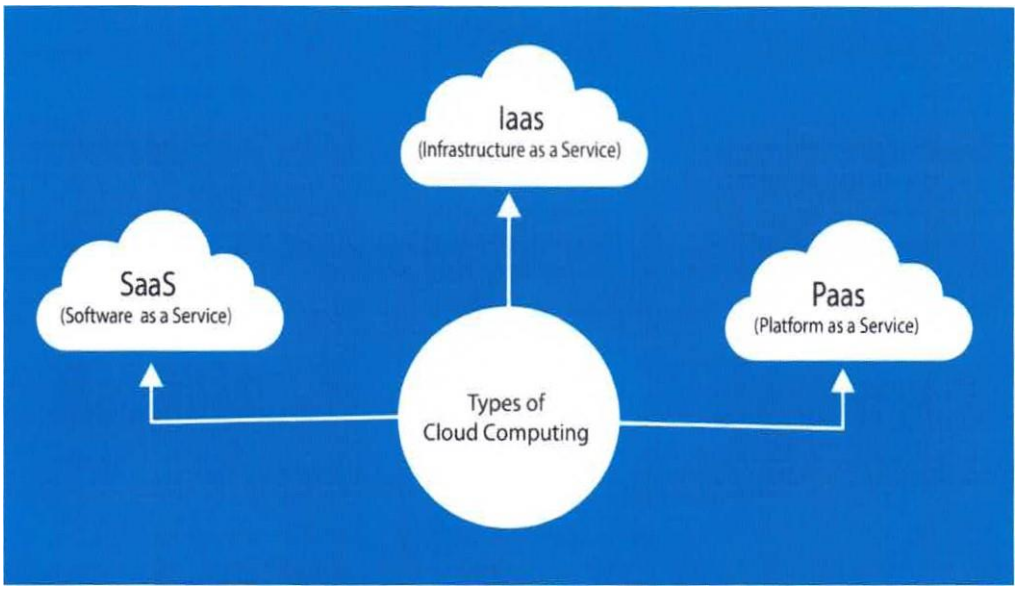

Figure 2. Three types of cloud computing services [4].

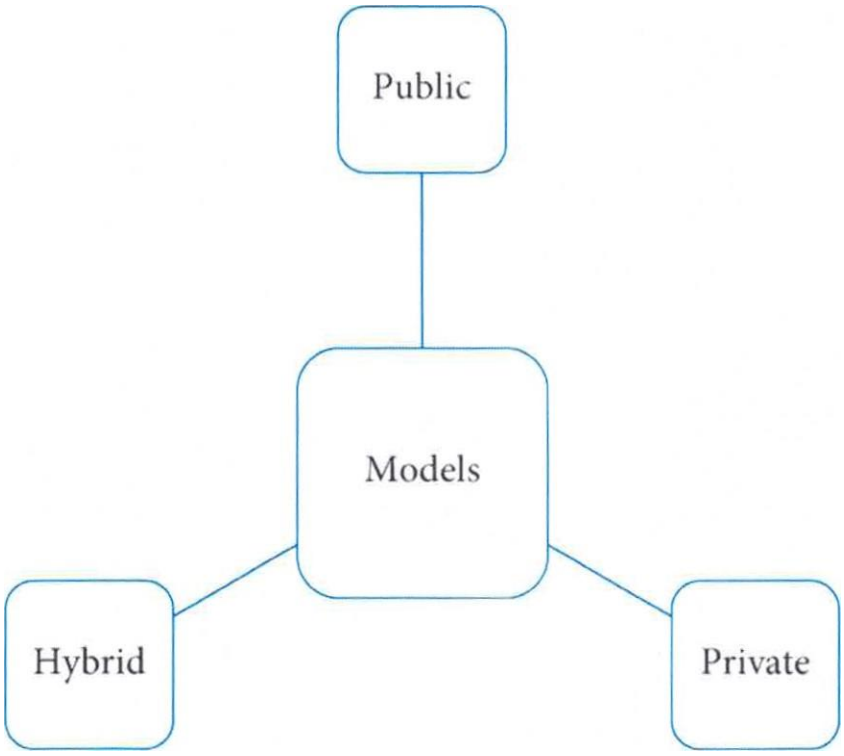

Figure 3. Cloud computing models [6].

Figure 4. Some cloud architects [2].

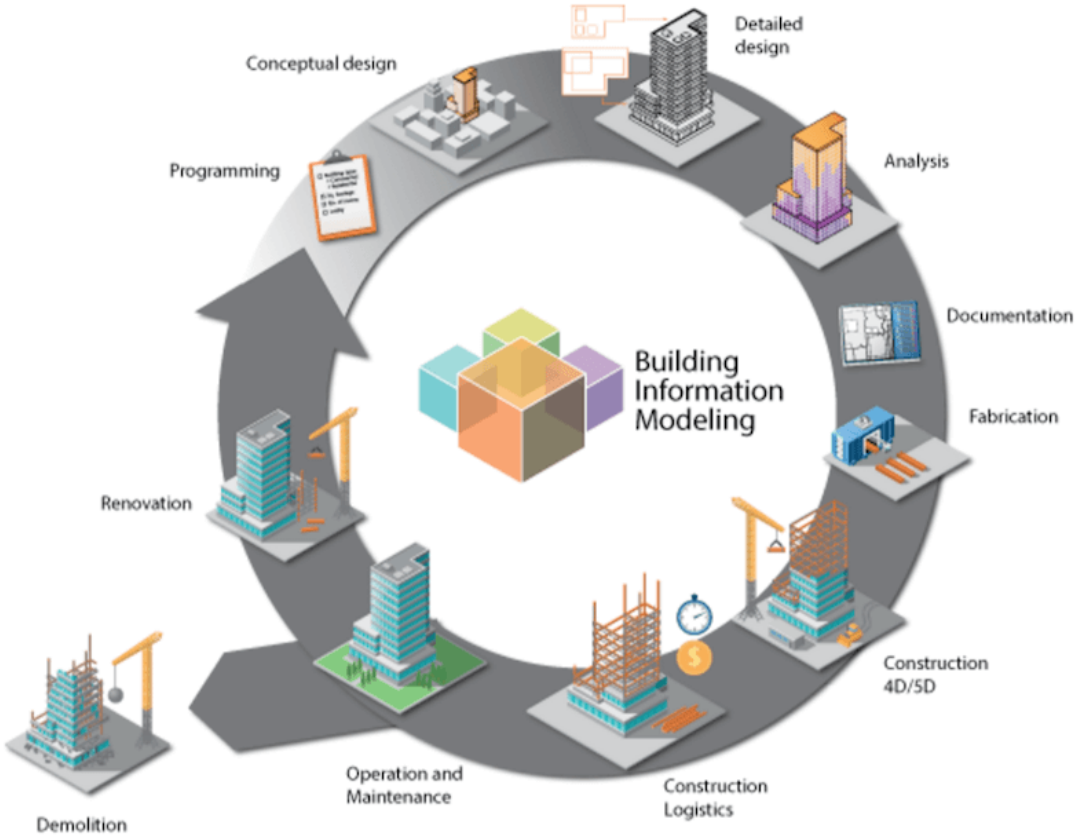

Figure 5. Components of BIM [10].

Figure 6. A typical construction site [9].

Figure 7. A hacker [12].