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Building Information Modeling for Architecture

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ABSTRACT

Building information modeling (BIM) is a way of representing a built asset as a digital model. It allows architects, engineers, and other stakeholders to explore every aspect of a building–foundations, surroundings, past configurations, and even possible futures. It is the foundation of digital transformation in the architecture, engineering, and construction (AEC) industry. It has emerged as a revolutionary force in the architecture industry, transforming the way buildings are designed, constructed, and maintained. BIM, the pinnacle of architectural innovation, has ushered in a new era of design possibilities. This paper is intended to provide the use of BIM in the architecture industry. It unveils how BIM empowers architects to transcend boundaries and reshape the architectural process.

KEYWORDS: building information modeling, BIM, architecture, engineering

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INTRODUCTION

In the world of architecture, engineering, and construction (AEC), technology has continuously played a vital role in shaping the way projects are designed, planned, and executed. In the intricate realm of architectural design, innovation constantly propels the industry forward. One such innovation that has redefined the landscape is building information modeling (BIM).

The architectural drafting industry has undergone a remarkable transformation. There was a time when architects would draw by hand every excruciating detail of their design. Gradually they started using machines for the job - computer-aided designing (CAD). And now we have BIM (building information modeling), which takes the CAD concept further by embedding intelligence into the design process. In the past, construction projects were a series of individual services which built on top of each other, whereas BIM is a project with a common data repository, that provides information to all stakeholders. BIM is a methodology that allows architects to create digital design simulations to manage all the information associated with an architectural project. It is an intelligent, 3D model-based tool that provides users with a digital representation of a facility's physical and functional characteristics. BIM is changing not only the way designs are generated, but our fundamental approach to construction in general. It allows seamless collaboration in real-time between all disciplines and all stakeholders. Figure 1 displays BIM project stakeholders, including architects, surveyors, engineers, contractors and the owner of the building itself [1]. BIM helps them get better connected and grow together as a community. Architects, surveyors, civil engineers, and structural engineers are professionals who use BIM to communicate information.

Architectural renderings are a valuable design and visualization asset that motivate and excites clients. A professional architectural rendering is shown in Figure 2 [1], while some architects are displayed in Figure 3 [1]. In addition to 3-D rendering capabilities, BIM uses data sets to factor in time considerations (the “fourth dimension”), financial parameters (the "fifth dimension"), and asset management (the "sixth dimension"). BIM helps make sense of increasingly complex structures, such as shown in Figure 4 [2]. 3D BIM models help architects, engineers, construction professionals, and facility managers better understand the entire project from start to finish.

BACKGROUND ON BUILDING INFORMATION MODELING

Building information modeling (BIM) is a digital representation of physical and functional characteristics of a facility. It is the holistic process of creating and managing information for a built asset. BIM is a digital representation of the physical and functional characteristics of a building or facility. The representation can be used to simulate the construction and operation of the facility, and to provide information for decision-making throughout the project lifecycle.

Building information models (BIMs) are computer files (often but not always in proprietary formats and containing proprietary data) which can be extracted, exchanged or networked to support decision-making regarding a built asset. The main objective of creating the models is to provide builders with all relevant information about the project in a digital format. BIM software (such as Revit, Microstation, Vectorworks, Infraworks, ArchiCAD, BIM 360, Formit, Civil 3D, GBS Tekla, etc.) allows the design team on a project to construct a 3D model that represents the one we intend to build. Two typical examples of 3D models used in BIM are presented in Figure 5 [3] and Figure 6 [4]. The BIM software is used by individuals, businesses and government agencies who plan, design, construct, operate and maintain buildings and diverse physical infrastructures, such as water, refuse, electricity, gas, communication utilities, roads, railways, bridges, ports and tunnels. The BIM concept envisages virtual construction of a facility prior to its actual physical construction, in order to reduce uncertainty, improve safety, work out problems, and simulate and analyze potential impacts. However, the use of BIM goes beyond the planning and design phase of a project, extending throughout the life cycle of the asset [5]. Figure 7 shows various components of BIM [2].

Though the 'B' in BIM stands for building, it covers all constructions in the AEC industry, from residential and industrial buildings to bridges and roads. The 'I' in BIM stands for information, referring to the integrated information within BIM models. This is its core concept - information, parameters, attributes, whatever we call it. The 'M' in BIM stands for modelling. BIM models are known to be condensed with data. Thus, BIM is not a type of software, but a holistic process for managing the building information. We use software and tools that aid the BIM process. BIM covers the entire cycle of the building, from design development to post-construction maintenance. It includes planning, designing, construction, and even operations [6].

AEC professionals relied on manual drawings for decades until CAD came into existence. Traditional building design was largely reliant upon two-dimensional technical drawings (plans, elevations, sections, etc.). Building information modeling extends the three primary spatial dimensions (width, height and depth). The model can contain all the physical and functional characteristics of a project, including structure, geometry, aesthetics, materials, systems, and dynamic performance. A 3D model becomes 4D if a time component is added, and 5D when cost-related information is included. BIM enables a virtual information model to be shared by the design team (architects, landscape architects, surveyors, civil, structural and building services engineers, etc.), the main contractor and subcontractors, and the owner/operator. It enables all the stakeholders to use the same shared 3D model, from architects to surveyors, engineers, contractors, to building owners. This allows everyone to have access to the relevant information at the right moment during the design and construction of a project.

The concept of BIM has existed since the 1970s, when architects and engineers began to explore the use of computer-aided design (CAD) software to create 3D models of buildings. The terms "Building Information Model" or "Building Information Management," and "Building Information Modeling" did not become popularly used until some 10 years later. BIM only became an agreed term in the early 2000s. BIM has evolved over the past few decades from simple 2D drafting to sophisticated 3D modeling with rich data integration. Figure 8 shows early developments of BIM [7]. Today, BIM is an essential tool for the AEC industry. It is used throughout the entire project lifecycle, from design and construction to operation and maintenance.

A comprehensive BIM modeling solution combines the major elements of building information modeling software, data repository, collaboration, analysis, visualization, and project management tools [4]. Different levels of BIM can be achieved for various types of projects**.** Below are brief descriptions of the levels [8]:

Level 0 BIM: Paper-based drawings + zero collaboration

Level 1 BIM: 2D construction drawings + some 3D modeling

Level 2 BIM: Teams work in their own 3D models

Level 3 BIM: Teams work with a shared 3D model

Level 4 BIM: Incorporating time-related data into the BIM model

Level 5 BIM: Integrating cost estimation and management within the BIM model

Level 6 BIM: Including sustainability data

Level 7 BIM: Used to manage and maintain facilities

BIM IN CONSTRUCTION

BIM in architecture refers to a digital process where architects create a 3D model of a building that contains detailed information about its components, allowing for comprehensive design visualization, analysis, coordination with other disciplines like engineering, and improved project management throughout the building's lifecycle, from conception to demolition. It is a term given to the process of creating, modifying, and analyzing all the information about a building. Common BIM software used by architects include Revit, ArchiCAD, Civil 3D, Autodesk Forma, and AllPlan. They are software with which BIM is compatible. A typical Revit screenshot is shown in Figure 9 [2].

Many architects, engineers, and thought leaders regard BIM as a disruptive force, changing the way building professionals design, build, and ultimately manage a built structure. BIM allows the joint work of architects, clients, builders, engineers, and other relevant actors to occur within in a single intelligent and shared process. Projects modeled in BIM can include the real products and materials that will be used to build them, incorporating their geometry, characteristics and cost into the model. Each of the elements has its own attributes and is related specifically and parametrically with the other objects of the project. If one of these objects is modified, those that depend on it will also change automatically.

BENEFITS

BIM spans the entire lifecycle of a construction project, from initial design to maintenance and operations. Its multidimensional approach offers unparalleled benefits across all phases of a project's lifecycle. It helps architects, engineers, and construction teams manage a project from start to finish. We are at a point where the majority of the buildings are being crafted digitally. In many nations, BIM is the government mandate for all public projects. Many companies are replacing their 2D CAD drawings with BIM files as a standard practice. Other benefits include the following [9,10]:

- *Visualization:* One of the key advantages of BIM in architecture is its ability to enhance visualization and design exploration. Construction teams can use these visualizations to plan more effectively, identify potential risks, and make informed decisions before breaking ground. BIM provides much greater visibility into design performance and construction processes. Architects can simulate and analyze issues, while contractors can use BIM to improve work planning, coordination, and quality control. They can also create detailed 3D models that accurately represent the building's form, materials, and systems. With 3D rendering services and architectural visualization, you can actually see the entire design even before starting the construction.
- *Collaboration:* BIM enables seamless collaboration between architects, engineers, contractors, and other stakeholders by providing a shared platform to access and update project information in real-time. It serves as a shared knowledge resource, allowing all project participants to access, modify, and contribute to the building information throughout its lifecycle. It provides a simple and intuitive way for team members to work together on a project since the data is stored on a cloud-based platform. Creating a single, digital source of truth that all stakeholders can access and contribute to empowers collaboration and speeds project delivery timelines. This collaborative approach promotes better decision-making, reduces errors, and minimizes rework during the construction process.
- *Communication:* One thing that defines all BIM platforms is the blending of age-old design strategies with phenomenal new data and communication capabilities. BIM can facilitate open communication between clients and project teams, reduce costly errors, and provide greater visibility into the project as a whole. BIM not only streamlines the communication and redesign process, it mitigates risk in the initial design phase.
- *Transparency:* BIM designs show building or infrastructure projects in their entirety. It bolsters teamwork and increases transparency throughout a project's lifespan, making each individual stakeholder in the process more accountable for their own tasks. The BIM process makes designs more transparent to all stakeholders so that they can ask more relevant questions that lead to quicker sign-offs for designs.

- *Risk Mitigation:* While clients are thrilled with the benefits of design-build construction projects, there are some drawbacks that make these efforts risky to architects and their construction contractor partners. When later design changes make costs go up, the architects and construction professionals must take a hit to their profits. The BIM process allows architects to quickly work up to more complete designs that give them realistic views of project costs.
- *Common Data Environment* (CDE): This is the central location where project members can go to access information. A CDE can reduce project bottlenecks and enable integrated data management across teams. All files, models, specifications, changes, approvals, and issues reside in a single platform to provide a high level of transparency.
- *Client Satisfaction:* The BIM process offers architects the chance to completely wow clients and secure follow-on work. By digitizing and showcasing every angle of your design, BIM helps you communicate your project vision and bring clients with you every step of the way. Architectural models and physical display models are highly effective communication tools – allowing people to visualize space, understand products and be captivated by design.
- *Civil Engineering:* BIM helps civil engineers digitally explore alternative design decisions, capture more detail, and enhance coordination. Using BIM increases accuracy, predictability, and understanding throughout project life cycles. The shared data and collaborative nature of BIM results in reduced risk, improved accuracy and constructability, and optimized designs.
- *Structural Engineering:* Structural design and engineering professionals use BIM to design, detail, document, and fabricate structural systems. BIM enables collaboration across the project team –helping to optimize designs, improve accuracy, and connect design to fabrication to deliver projects faster and more efficiently. With BIM, architects and structural engineers can get invaluable support throughout the project lifecycle in a collaborative digital environment.
- *Clash Detection:* BIM identifies potential conflicts between different building elements early in the design phase, minimizing costly construction delays and rework. Clash detection and other issue detection capabilities help teams identify and correct problems before construction when changes are easier to make. This proactive problem-solving helps reduce costly mistakes and project delays.
- *Cost Efficiency:* By streamlining processes, minimizing errors, and improving coordination, BIM can significantly reduce project costs and construction timelines. Architects can use BIM data to optimize building designs for energy efficiency, minimize resource consumption, and reduce waste during construction and operation. Early detection of potential issues and optimized material usage can reduce construction costs. Architects and engineers can automate many repetitive tasks using BIM and focus their time on design quality.
- *Improved Design:* Errors happen. Your design is subject to mistakes. By using the BIM process and the associated software, architects avoid some of the mistakes. Many BIM tools have clash detection features built into them, which automatically detect certain errors. This allows designers to correct mistakes and improve their finished design.

CHALLENGES

While BIM offers numerous benefits, its implementation can present several challenges that need to be addressed. While the implementation of BIM may present challenges, the long-term advantages it offers are undeniable. Some challenges of BIM in architecture include the following [11,12]:

- *Cost:* One of the primary challenges is the initial investment required for software, hardware, and training. Adopting BIM often involves significant upfront costs, which can be a barrier for smaller organizations with limited resources.
- *Interoperability:* Data management and interoperability are critical considerations. As BIM models become more complex and data-intensive, managing and maintaining this information can be a daunting task. Ensuring seamless data exchange and compatibility between different software platforms and stakeholders is crucial for successful BIM implementation.
- *Cultural Shift:* Another challenge is the cultural shift required within organizations. Adopting BIM involves changing traditional workflows, processes, and mindsets. Resistance to change and a lack of buy-in from team members can hinder the effective implementation of BIM.
- *Sustainability:* In today's environmentally conscious world, sustainable, and energy-efficient building practices are becoming increasingly

important. By analyzing factors such as building orientation, material selection, and system performance, architects can make informed decisions to reduce energy consumption, minimize environmental impact, and achieve sustainability goals.

- *Standards:* To ensure interoperability and standardization across the industry, various organizations have developed BIM standards and guidelines. These standards facilitate seamless data exchange and collaboration among project stakeholders, regardless of the software or tools they use. One of the most widely adopted standards is the Industry Foundation Classes (IFC), developed by Building SMART International. The IFC standard is registered under ISO 16739. IFC is an open standard in the building and construction industry for digital description of building models during the BIM process. Figure 10 shows the various components of IFC [13]. Another important standard is the National BIM Standards (NBIMS).
- *Emerging Technologies:* Industry experts predict that adopting emerging technologies will only accelerate, driven by the increasing demand for more efficient, sustainable, and collaborative design processes. Integrating emerging technologies, such as virtual reality, augmented reality, artificial intelligence, and Internet of things, with BIM and 3D modeling will further enhance the architectural drafting landscape.
- *Specialized Expertise:* As the architectural industry embraces the power of BIM and 3D modeling, the need for specialized expertise and round-the-clock support has become increasingly crucial. This has led to the rise of outsourcing as a strategic solution, allowing architectural firms to leverage global talent and resources to enhance their drafting capabilities.
- *Outsourcing:* As the architecture industry continues to evolve, the strategic advantage of outsourcing architectural drafting services becomes increasingly apparent. By partnering with experienced BIM and CAD drafting service providers, architectural companies can access the latest technologies, specialized expertise, and efficient workflows. This allows them to focus on their core competencies and deliver exceptional designs. Outsourcing can provide a range of benefits, including increased productivity, cost savings, and access to a global pool of talent.

CONCLUSION

The impact that evolving technology such as BIM has had on today's architectural community is too great to ignore. This cutting-edge technology offers a comprehensive and collaborative approach to project management, enabling architects, engineers, contractors, and stakeholders to work together seamlessly. BIM is well on its way to becoming a non-negotiable standard for architectural companies that want to compete for work in the future. If the construction industry wants to work toward a brighter future, embracing innovation and forward-thinking technologies clearly is the only path forward. While BIM is a game-changer for the entire construction industry, it has particular benefits for architects.

(BIM) has revolutionized the architecture, engineering, and construction (AEC) industry, offering a collaborative and efficient approach to design and construction projects. As the architecture industry continues to evolve, BIM has emerged as a transformative force, redefining the way buildings are designed, constructed, and managed. By embracing BIM, architects can unlock a wealth of benefits, including improved visualization, enhanced collaboration, cost and time savings, and sustainable building practices. With its 3D modeling capabilities, data integration, and lifecycle management features, BIM has become an indispensable tool for architects, engineers, contractors, and facility managers. More information on BIM for the architecture industry is available from the books in [14-27] and in the following related journals:

- Construction Magazine
- Buildings
- Journal of Building Engineering
- Journal of Construction Engineering and Management
- WIT Transactions on The Built Environment

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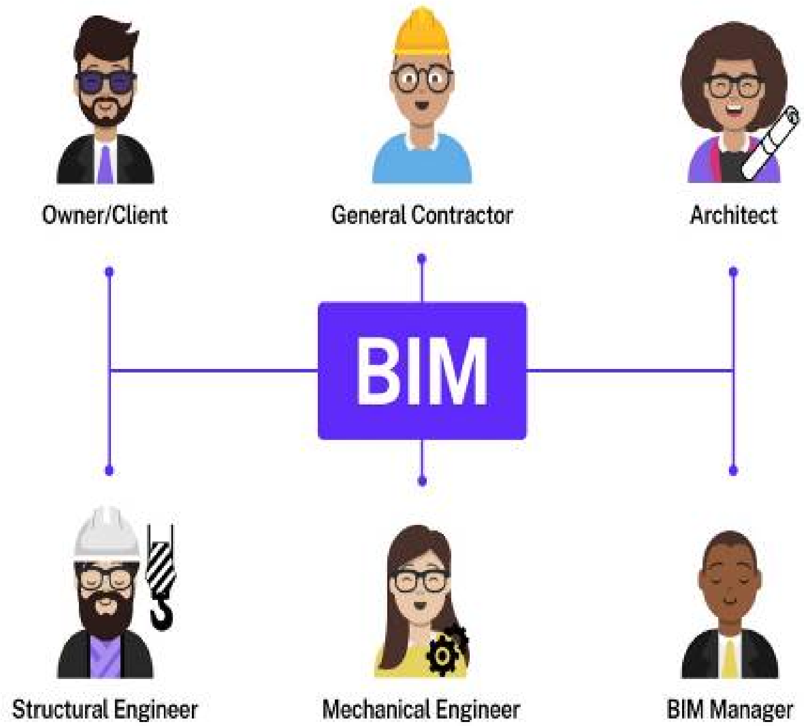

Figure 1 BIM project stakeholders [1].

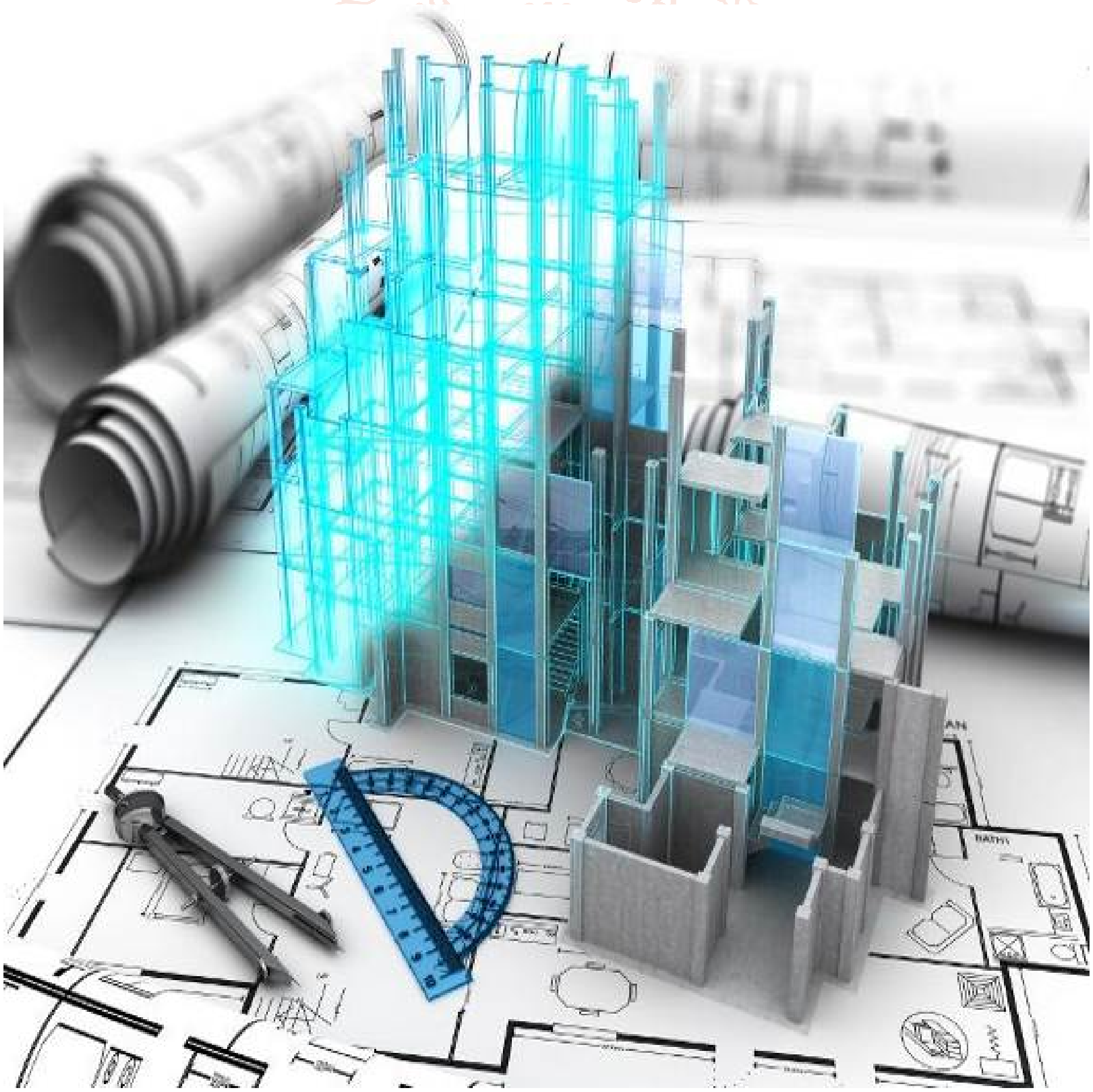

Figure 2 A professional architectural rendering [1].

Figure 3 Some architects [1].

Figure 4 BIM helps make sense of increasingly complex structures such as this [2].

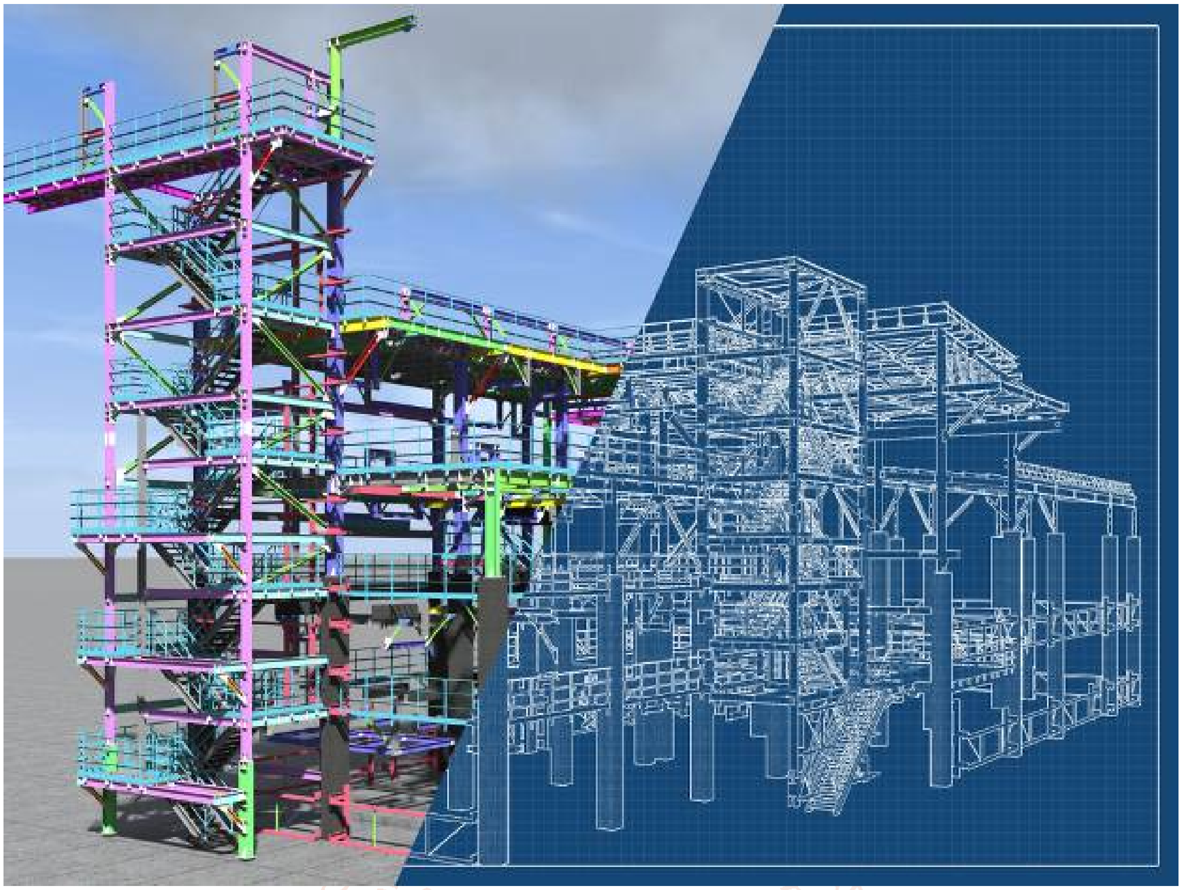

Figure 5 A typical 3D model used in BIM [3].

Figure 6 Another example of 3D model used in BIM [4].

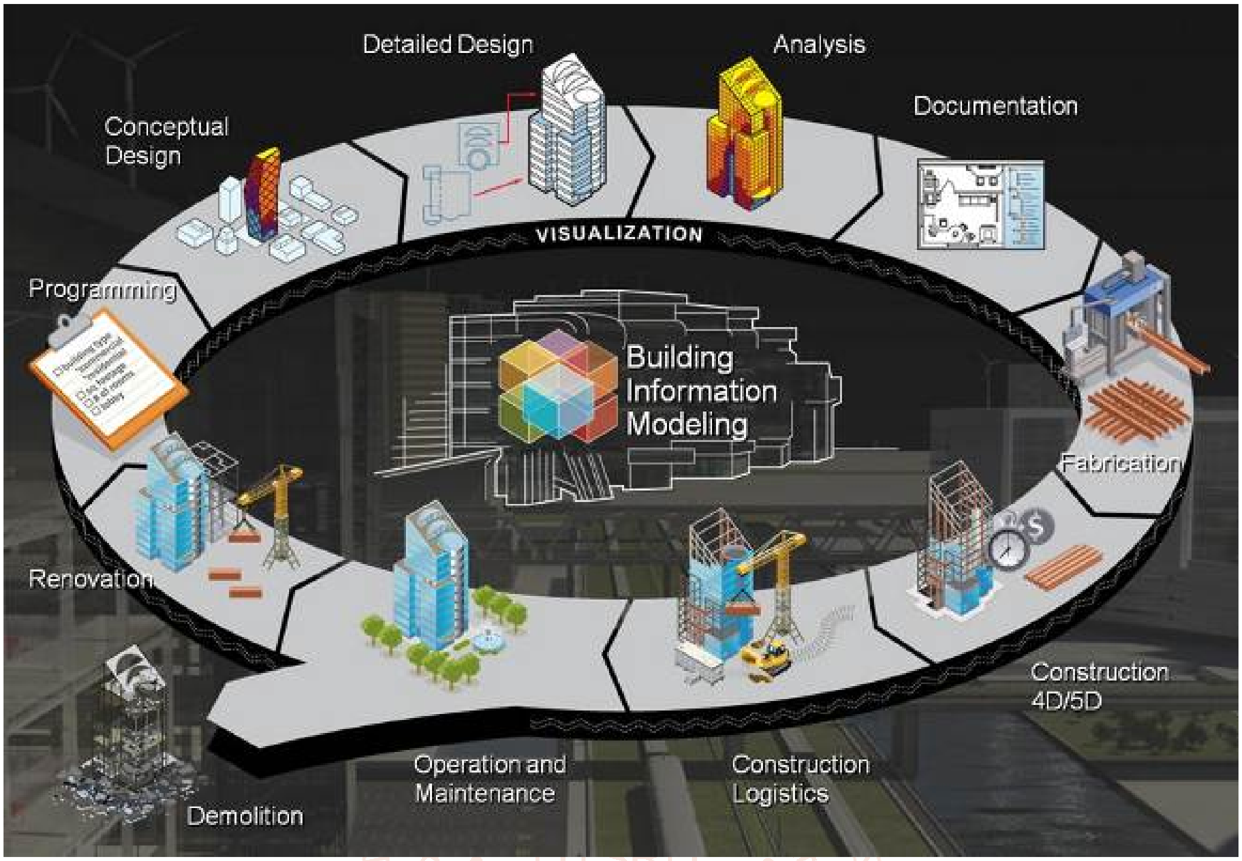

Figure 7 Various components of BIM [2].

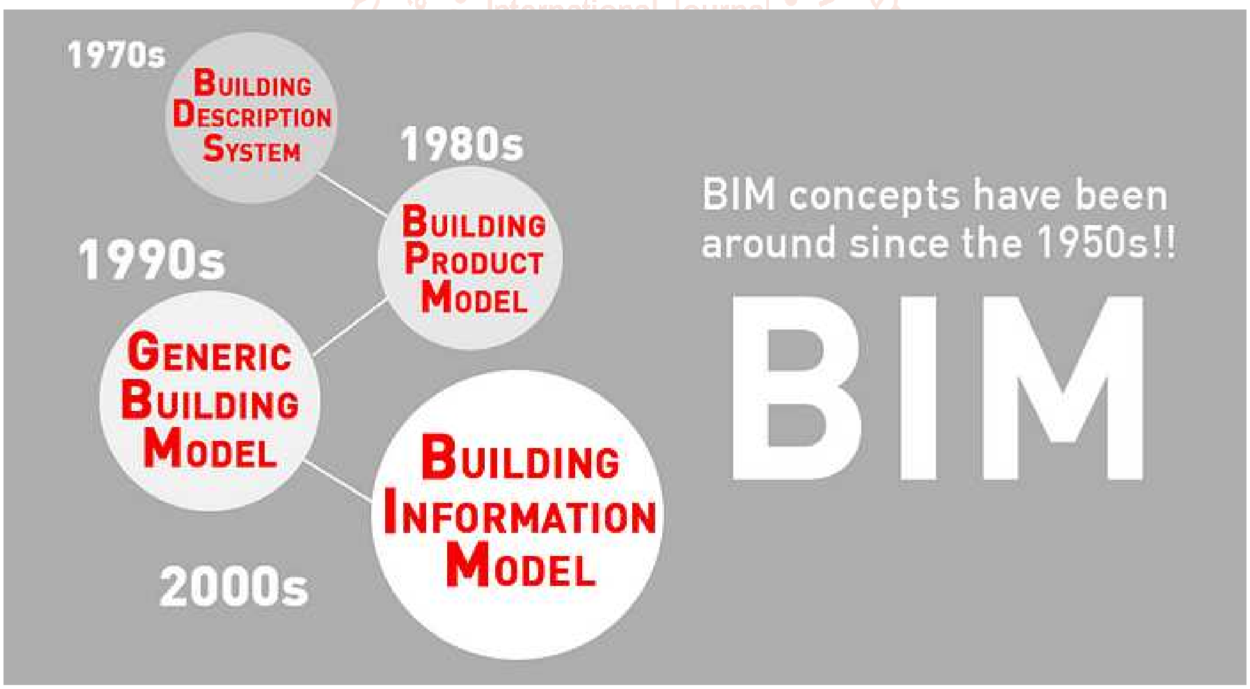

Figure 8 Early developments of BIM [6].

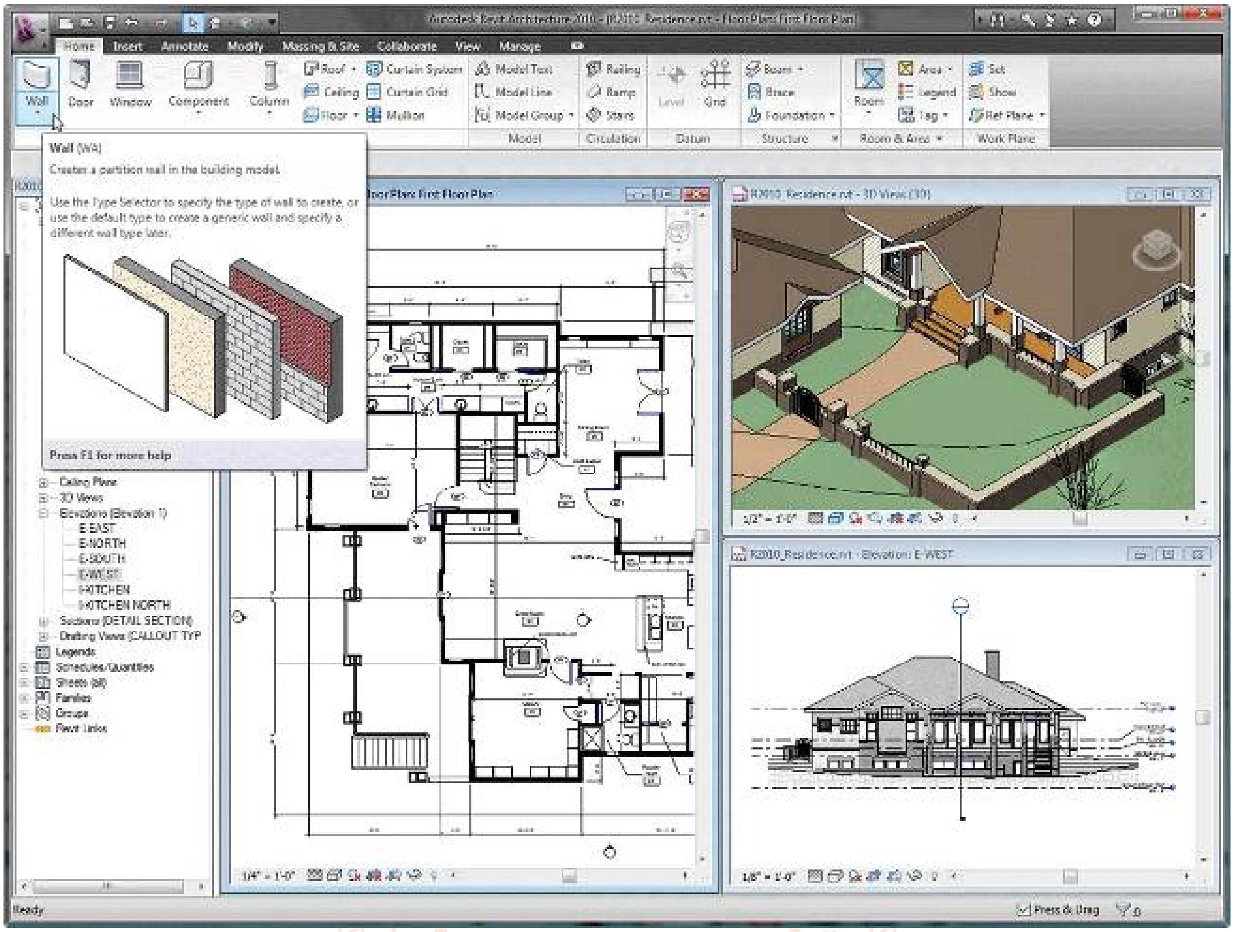

Figure 9 A typical Revit screenshot [2].

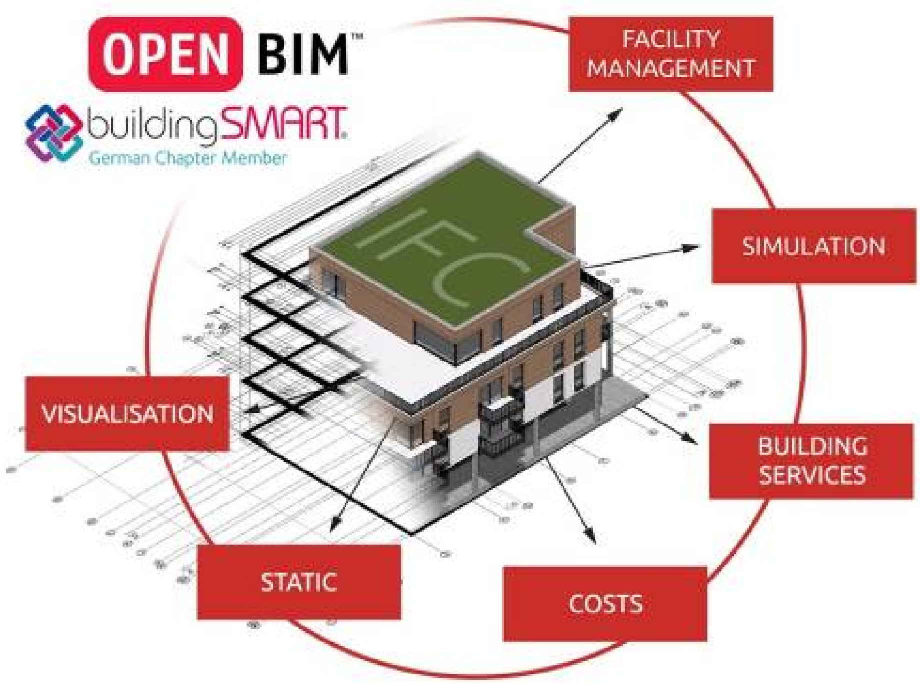

Figure 10 Components of IFC [13].