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Research Article

The Impact of Building Information Modelling (BIM) in the Construction Industry

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Abstract

Building Information Modelling (BIM) is a technique that enhances construction management. The BIM's capacity to create a model that can be used from the building's inception all the way through its construction and eventual occupancy is one of its primary benefits. Because of this benefit, it can be considered a fundamental part of construction management. BIM is a crucial tool for construction management, but its use is still in its infancy in some countries as this study shows. Therefore, this article aims to assess the impact of BIM as a tool for construction management in different parts of the globe and their adoption rates and by extension, identify ways to enhance or otherwise facilitate its application in the construction sector at the global level.

1. Introduction

The term "building information modeling" (BIM) refers to a procedure involving the creation and administration of digital representations of the physical and functional properties of places, and it is backed by a wide range of tools, technologies, and contracts. Building information models (BIMs) are computer files (often but not always in proprietary formats and including proprietary data) that aid in making decisions about a created asset (Watt, 2015). Planning, designing, building, operating, and maintaining buildings and various physical infrastructures like water, trash, electricity, gas, communication utilities, roads, trains, bridges, ports, and tunnels all make use of BIM software (Khosrowshahi, 2017; Ismail, 2021).

Although the idea of building information modeling (BIM) has been around since the 1970s, the term wasn't widely adopted until the early 2000s (Martens, 2015; Burry, 2015). Different countries have moved at different rates when it comes to developing and adopting BIM standards; norms produced in the United Kingdom beginning in 2007 served as the foundation for the international standard ISO 19650, which was released in January 2019 (Randy Deutsch, 2019). Every country relies on the construction industry to provide essential services like transport systems, industrialization, building systems, water utilities, wastewater treatment, and more. One of the world's major employers, this sector can be roughly broken down into three categories: the building of horizontal and vertical structures; the building of specific civil engineering structures; and the construction business, like other sectors such as manufacturing and communications, is highly dependent on the ever-increasing pace of technological advancement. Some well-known features that have proven useful in exponential systems are also incorporated (Ames, 1999). Digital innovations, experimentation, crowd sourcing, etc., are being incorporated into the construction business. As with smartphone software, the tools and software used to aid construction services are also undergoing regular updates; for example, AutoCAD has gone from version 2000 all the way up to AutoCAD 2021, and now we have BIM, or Building Information Modelling, to help us move from the second dimension to the fifth dimension even more quickly. Management practices for building projects have likewise progressed from the conventional to the contemporary (Lu et al., 2018). The old approach to construction procurement has given way to the more collaborative and modern Design and Build Construction as a result of Private Investment Schemes of Public-Private Partnerships (PPP) (Owen, 2021). Technology such as global positioning systems (GPS) in transportation engineering, algorithms in engineering structures, electronic bidding, virtual reality, computer software compatibility and interoperability, etc., have all found their way into the building industry (Fernando, 2009; Sacks et al., 2017).

Building Information Models (BIM) have been helpful in the construction industry because they put all the information about a project into one digital model and make it easier for the different people working on it to talk to each other and work together (Mogbo Onyebuchi, Olu Sunday, Tiza Michael, 2018; Johansson et al., 2015). Architecture, structural engineering, mechanical engineering, electrical engineering, and plumbing can all work together on a construction project with the help of this technology (Johansson et al., 2015). Some unskilled clients had trouble figuring out the needed 3D drawing of the project, and this application solves that problem. It also helps business owners and managers track how much work was completed over the course of a given time period in relation to the total amount spent (Johansson et al., 2015; Fernando, 2009; Sacks et al., 2017).

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2. Building Information Models (BIM)

2.1. The application of BIM within the framework of project management.

In spite of tight budgets, a lack of accessible resources, a rushed deadline, and confusing or contradictory information, the construction business is staffed with people who are expected to deliver successful projects (Race, 2019). Given that it is mathematically impossible for two events to take place at the same time and in the same place, it is of the utmost importance that the designs of the major disciplines, such as architecture, structure, and MEP, be well-coordinated. In addition, BIM can be used to assist in the detection of collisions by highlighting areas in which discrepancies exist (Du, 2020). The Building Information Modeling (BIM) concept proposes the virtual construction of a facility prior to its actual physical construction. This is intended to reduce risk, improve security, smooth out kinks, and simulate and evaluate potential repercussions (Moshtaghian & Noorzai, 2022).

Before construction begins, subcontractors from every trade can submit critical data to the model, which increases the probability that some systems can be pre-fabricated or pre-assembled off-site (Quan, 2021). On-site waste reduction is one of the options, as is just-in-time delivery of products rather than stockpiling of supplies. Calculating material amounts and commonality does not present much of a challenge. It is possible to distinguish between and specify different work scopes. It is possible to present systems, assemblies, and sequences in context with the entirety of the facility or a cluster of facilities (Du, 2019). Because BIM has the capability to facilitate conflict or "clash detection," errors can be avoided thanks to this feature. In this scenario, the computer model visibly shows the team where sections of the structure (for example, the structural frame and the building services pipes or ducts) may erroneously meet, thereby preventing mistakes that could be very expensive (Huang, 2014; Wen, 2021).

2.2. The administration of the building information model

The process of building information modeling encompasses every stage, beginning with preliminary planning and continuing all the way through to the point where the structure is ready to be occupied. During this period of time, it is possible to hire a BIM manager to oversee the operations of the information management system (Atazadeh et al., 2016). A design-build team will appoint a BIM manager on behalf of the client from the beginning of the pre-design phase and continue to do so for the entirety of the project life cycle. This person is accountable for designing and monitoring the object-oriented BIM against the performance objectives that have been anticipated and tracked, in addition to providing assistance for the multi-disciplinary building data models that enable analysis, scheduling, take-off, and logistics (Pruyt, 2015). Many companies are currently investigating the feasibility of developing building information models (BIMs) at a wide range of levels of complexity. This is due to the fact that the level of depth required for a given application of BIM varies, as does the amount of modeling work involved in producing building information models at various levels of detail (James, 2022).

2.3. Building Information Modeling's Integration into Facility Operations

Throughout history, once a construction project was finished, the builders had very little say in how the facility was used after it was finished. It was up to the building owner or manager to take care of that until it became essential to do maintenance or updates (Gundu & Modiba, 2020). However, the BIM-created 3D models have such a high level of detail and are so simple to communicate that a wealth of operational data and insight can be sent along to the building owner and manager, enhancing their capacity to run the building at maximum efficiency (Chen, 2019). This is made possible because the BIM-created 3D models are so simple to communicate with (Halmetoja & Lepkova, 2022; Maher, 2018).

This benefit of BIM is consistent with the concepts of sustainable construction, which aim to limit negative impacts on the environment across all stages of the life cycle of a structure. BIM's ability to do this helps to ensure that these principles are followed (Mannino et al., 2021). To get the most out of this benefit of the BIM process, forward-thinking construction professionals are integrating recommendations for long-term operations and maintenance schedules that are cognizant of the environment into the final parameters of their projects. Because of this, the long-term viability of the building as a whole is improved, and the relationship that the business maintains with each individual customer is fortified. You could definitely come up with a great number of additional ways in which incorporating BIM technology and methodology might potentially boost the long-term sustainability of building projects in your particular setting (Rasys et al., 2014).

Because it enables the design team, the construction team, and the building owner or operator to add to and refer back to all of the information they learn throughout the course of their contribution to the BIM model, Building Information Modeling (BIM) helps bridge the information loss that is associated with handling a project from one group to the next (Tian & Liu, 2014). As a consequence of this, the manager of the facility could have certain favorable outcomes. For instance, the owner of a building that has developed a leak may find out about the harm that has resulted from the leak. Because of the model, he can tell at a glance whether or not the region is secure due to the fact that he can see that a water valve is located there. This allows him to save both time and effort.

Assuming he had the appropriate computational capacity, he would also be able to incorporate specifics in the model such as the size of the valve, the manufacturer, the component number, and many more (Williams et al., 2019). Leite and Akinci were the first people to face such challenges head-on when they created a vulnerability representation of facility contents and threats to assist in discovering vulnerabilities in building emergencies. This was done in order to help identify vulnerabilities in buildings. The BIM software can also incorporate dynamic information about the building, such as sensor readings and control signals from the building systems, in order to assist in the analysis of building operation and maintenance (Kumar & McArthur, 2015; Wildenauer et al., 2022).

There have been efforts made to construct information models for structures that have previously been erected. Referring to key metrics such as the Facility Condition Index (FCI), carrying out 3D laser-scanning surveys and photogrammetry techniques (either individually or in combination), and digitizing conventional building surveying techniques through the use of mobile technology to acquire precise measurements and operational details are some of the methods that can be used to create a model of an asset (Mike, 2022). Because of the numerous assumptions that need to be made regarding design standards, building rules, construction methods, materials, and so on, it is more difficult to structure a model of a building that was erected in an earlier year, say 1927, than it is to do so during the design process (Näser & Wickenhagen, 2018; Mike, 2022 & Wildenauer et al., 2022).

In order to properly maintain and manage existing facilities, one of the challenges that must be overcome is gaining an understanding of how BIM can be utilized to support a holistic understanding of building management practices and the "cost of ownership" principles that underpin their implementation. These practices and principles must be able to support the full product lifecycle of a building. Building information modeling (BIM) is incorporated into the American National Standard APPA 1000 - Total Cost of Ownership for Facilities Asset Management to account for various critical requirements and costs over the life-cycle of the building (Jodh, 2022; Näser & Wickenhagen, 2018). These critical requirements and costs include the cost of replacing energy, utility, and safety systems; the cost of regularly maintaining the building's exterior and interior; the cost of replacing materials; the cost of implementing changes to the building's design; and the cost of regularly maintaining the building's exterior and interior. Building information (Näser & Wickenhagen, 2018; Mike, 2022).

2.4. BIM and the Idea of an Eco-Friendly(Green) Building

It seems appropriate to say that "The new age is exploring green architecture" in reference to a society that is in the process of evolving but which appears to be moving forward at the expense of the environment (Kensek et al., 2016).Even though there are a number of other factors that play a role, structures play a vital role in the progression of climate change (Larsson & Cole, 2001).Therefore, environmentally friendly building practices are a response to this developing risk.The urban heat islands that form over expanding cities; pollution from industries; and carbon emissions from buildings are three of the most significant factors that contribute to global warming.Green buildings have the potential to significantly minimize their impact in this environment (Haider & Hafeez, 2021; Larsson & Cole, 2001).

It is possible to construct environmentally friendly buildings by using processes, equipment, and materials that reduce the amount of power and resources required by the structure.Local production of green buildings, as opposed to production in a factory, would be necessary for a further reduction of the structures' negative effects on the environment(Kensek et al., 2016; Haider & Hafeez, 2021; Larsson & Cole, 2001).Green buildings make use of local resources by repurposing and recycling waste items from construction and demolition operations. This reduces the amount of waste generated by these types of projects.Use of Water Management: A green building will feature water treatment systems as well as rainwater collection systems in order to collect and store water for use at a later time (Haider & Hafeez, 2021).In order to keep the amount of usage under control, they would use water-saving equipment.Green buildings are ones that include landscape and nature-centered design ideas, such as the use of indoor and outdoor plants to produce healthy and happy indoor settings. Another example of a green building is the use of solar panels to generate electricity for the structure (Krygiel & Nies, 2008; Valinejadshoubi & Bagchi, 2015). The presence of plants and trees on the property not only contributes to a reduction in CO_2 levels but also helps to keep the indoor air quality in a healthy and pleasurable state. Installing green-rated appliances, which consume less energy and load, reduces the overall need for heating, ventilation, and air conditioning (HVAC) as well as power (Arayici et al., 2017; Sacks et al., 2018). The use of solar panels and other forms of renewable energy is another component of "green" building practices. These buildings often have intelligent technology integrated into the design of their facades in order to reduce the impact of the surrounding environment on the interiors of the building and maintain the energy efficiency of the structures. Louvres, smart facades, and other similar elements are able to make a significant dent in the amount of energy that a building consumes when they are installed. Utilizing Building Information Modeling (BIM) and other techniques that are similar can be of assistance while attempting to construct environmentally friendly buildings (Ofluoglu et al., 2020).

2.5. The significance of integrating BIM in environmentally friendly buildings

The green building movement is comprised of three main tenets: the environmentally responsible design, construction, and operation of structures. It is an admirable goal, but accomplishing it is not always a simple task. Its final success will be determined by a number of factors, including the short-term and long-term expenses, as well as the construction methods and strategies that are utilized. It has been proposed that the implementation of BIM services could be an industry-changing factor in the field of environmentally conscious construction (Wu et al., 2017; Kaparaju et al., 2018).

There are a lot of people who work in the construction sector that see this as a method to boost productivity without sacrificing quality (Kaparaju et al., 2018; Sun et al., 2022). Service providers of Building Information Modeling (BIM) can be of assistance by providing tools for analyzing and comparing a variety of sustainable choices, cutting down on energy use, reducing waste, and reducing operational costs. Building information modeling (BIM) services, such as conceptual modeling and topography modeling, offer a novel approach to environmentally friendly construction by making accurate and up-to-date project details instantly and permanently accessible. This paves the way for more eco-friendly building practices(Kaparaju et al., 2018; Sun et al., 2022 & Wu et al., 2017).

2.6. The role of BIM in green Buildings

The revolutionary aspect of BIM's green construction strategy is that it takes a comprehensive approach. It makes possible a level of design precision that has never been conceivable before, which has positive consequences both for the natural world and for the construction industry. By employing sustainable, green building design approaches and workflows, BIM services make it possible to construct buildings that improve the context in which analysis and decision making may take place. In green building design, the benefits of using BIM include the following: Both our efficiency and our production have room for improvement. Analytical tools can be employed in conjunction with digital models in order to more easily weigh the benefits and drawbacks of environmentally friendly choices (Douglass & Leake, 2019). It is possible to save digital models, both preliminary and final, and to access and share those models indefinitely. It is feasible to provide the findings of intricate computations and in-depth evaluations of various environmentally friendly choices in an approachable manner (Reyna, 2022). Enhanced collaboration amongst various stakeholder's Real performance measurements are combined with the design characteristics, specifications, and parameters for the materials and surfaces. With improved visualization, teams will find it much simpler to demonstrate to clients the advantages that various environmentally responsible design options offer (Mukherji, 2011; Reyna, 2022). During the pre-construction phase, digital models can be improved through analysis and design decisions, providing builders with a preview of the finished project in a manner that is nearly identical to real time. In addition, stakeholders can look into specific changes in light of final, irreversible building decisions (like where to put a building). They are now able to quantify the decisions that lead to the greatest success as a result of their understanding of the effects that the environment and the elements have on them. Build Information Modeling, also known as BIM, is a technique used in the construction industry to collect both visible and non-visual data (Clarke, 2007; Liu & Wang, 2021). The construction crew is able to record progress reports on demolition and building thanks to the capabilities of BIM, which records changes to the state of the materials that are being utilized (Maskil-Leitan et al., 2020). The capacity of Building Information Modeling (BIM) to combine digital models with energy analysis methodologies like conceptual modeling and topography modeling makes it possible to conduct accurate and consistent evaluations (Kubba, 2012; Kibert, 2016).

2.7. Modeling of the Topography of the Terrain (for solar and shadow analysis)

The utilization of passive design concepts is predicated on the utilization of natural resources such as sunshine and solar energy to a significant extent. With the use of various software tools that are made accessible to designers and BIM service providers, solar and shadow impacts, as well as essential components of those impacts, can be better seen or measured (Aramesh et al., 2017). If they are employed at the beginning of a project, they can provide light on topics such as how much shade a certain design receives from its environment, whether or not that design throws any shadows, and which shading approaches could be the most successful in the long run (Nguyen, 2020). It is essential to make a detailed plan that takes into account the route that the sun will take across a site as well as the shadows that will be created by neighboring objects and the structure itself. This information can be useful for future design evaluations, particularly those that take into account solar heat gain, daylighting, and solar electricity generation (Liu & Mason, 2016; Jain et al., 2020).

3. Worldwide Adoption of Building Information Modeling

As more and more people in the building business learn about BIM and its advantages, its use is expanding throughout the world (Rell, 2022). American computer scientist and Internet pioneer Ivan Edward Sutherland, sometimes known as the "father of computer graphics," created the first graphical user interface (GUI) computer-aided design (CAD) program, "Sketchpad," in 1963 (Henderson, 2009). Besides being a pioneer in the field of human-computer interaction, Sketchpad also paved the way for new kinds of modeling software to be used in the building trades (Lach, 2020; Eastman et al., 2011).In the 1970s and 1980s, Sketchpad helped cement the display and recording of shape data through the computational representation of geometry in building technology.In a 1986 article titled "Automation in Construction," Robert Aish recorded the term "Building Modelling," the forerunner of today's "Building Information Modelling" or "BIM," which was first used in a paper by G.A. Van Nederveen and F. Tolman in December 1992 (Ghanim, 2022) .Since then, BIM has been revolutionizing the building sector.The building industry all over is embracing new technology in hopes of streamlining the process.As the number of people living in cities continues to grow, governments throughout the world are paying greater attention to the concept of "smart cities."In terms of infrastructure development, a country that embraces BIM may become a global leader.Let's see how BIM adoption is going in various nations (Ghanim, 2022; Lach, 2020; Eastman et al., 2011) .

- **Germany**

In 2015, the German government announced the establishment of the Digital Building Platform, an industry-led BIM task force established by many organizations (Emmanuel Di Giacomo, 2015).To paraphrase from the official government statement: "standardize process and device descriptions; develop guidelines for digital planning methods; and provide sample contracts."Public infrastructure projects will be required to use BIM by 2020, thanks in large part to the government's active participation in promoting it(Blömer, 2016;Paul, 2020).

- **USA**

The United States began adopting BIM in the 1970s, long before its widespread adoption and use in the 1990s.Being an early adopter, however, does not always pay off.As time went on, the United States' BIM adoption pace slowed to the point that other nations might learn from the United States' mistakes and speed up their own BIM adoption processes (James Vandezande, 2019; O'Malley, 2022).The government has not required BIM use as of yet.Even so, that doesn't mean technology isn't being taken seriously in the country.Various government agencies have developed their own standards and presented them in conferences hosted by organizations like the National Institute of Building Sciences. Nevertheless, these norms have not been developed in concert with one another (Paul, 2020).

In 2003, the US General Services Administration (GSA) established the National 3D-4D-BIM Program.As part of this initiative, the Public Buildings Service is now required to use BIM on all future construction and renovation projects.In 2013, Wisconsin made history by becoming the first state to require BIM for all government-funded projects costing more than $5 million (O'Malley, 2022).The potential of BIM adoption is further demonstrated by examples of successful implementation, such as the Los Angeles Community College District (LACCD).The United States is making great strides in BIM adoption, although slowly.In recent years, Building Information Modeling (BIM) has emerged as a crucial resource in the AEC (Architecture, Engineering, and Construction) sector in the United States.Opportunities await BIM-focused businesses thanks to rising levels of private finance for building projects and the US government's plan to encourage investments in infrastructure (Excelize, 2021).Recently, the US government unveiled a proposal to invest $200 billion in federal funds over the next decade to encourage an additional $1.3 trillion in expenditure from local governments, state governments, and private businesses on massive infrastructure projects.One of the major building markets is the United States, with 2017 spending of approximately $1.1 billion.Growth in the urban population and rising government expenditure are two of the most important trends in the market, both of which present excellent opportunities for businesses that focus on cutting-edge technological innovations (Paul, 2020; Excelize, 2021).

- **Denmark**

Rising interest in building information modeling (BIM) in Denmark is a result of the substantial cost savings and improved service quality it may provide. In Denmark, BIM is being used in the majority of large-scale projects. The government at all levels is shifting to digital channels. When it comes to mandating BIM, the government has been in the forefront. Standards are established, and semi-government groups take the lead in setting the bar for practical solutions (Anker Jensen & Ingi Jóhannesson, 2013).The promotion of classification systems provides the groundwork for the success of multidisciplinary endeavors (Lu & Anumba, 2022).When it comes to building information modeling (BIM), virtual design and construction (VDC), and prefabrication, Denmark is often considered a pioneer (Carpino et al., 2020; Paul, 2020).

- **UAE**

The Dubai Municipality issued circular (196) in 2013 requiring BIM (Building Information Modeling) for all architecture and mechanical, electrical, and plumbing (MEP) projects.Subsequently, in 2015, circular (207) expanded this to include architectural and mechanical work for buildings with more than 20 stories; buildings, facilities, and compounds with areas greater than 200,000 square feet; buildings and special facilities like hospitals and universities; governmental projects; and projects by foreign offices.Few standards, however, have been established for the use of BIM in the UAE as of yet (Baik & Boehm, 2017).

Due to its many advantages, BIM is being widely used by the UAE's building sector.Herriot-Watt University conducted a poll in 2015 of over 500 AEC professionals working on building projects in the UAE, and found that 87% have utilized BIM in their businesses, with 62% using it for more than one project.A majority, 52%, thought that BIM would be widely employed in the UAE in fewer than five years.Still, the BIM methodology has not been standardized across the UAE building sector alongside this development.There is still more work to be done to pave the way for wider dissemination and use (Baik & Boehm, 2017; Paul, 2020 & Baik, 2020).

- **Japan**

BIM's popularity has grown over the past few years, but the country's formal BIM adoption has moved slowly.When it comes to construction in Japan, the MLIT is the ministry in charge.A number of BIM pilot projects were launched by MLIT back in 2010.In March of 2014, it released its BIM guidelines, which will be the first national BIM Protocol in the country by 2017.When a contractor (architect or builder) decides to use BIM on his own or when technical studies are required based on a proposal, this MLIT BIM guideline is applied to public projects.According to this standard, it is not required to employ building information modeling (Baik, 2020).In July 2012, the Japan Institute of Architects (JIA) published a BIM guidance document.The protocol's emphasis is on defining BIM and exploring its applications.When compared to the MLIT guidelines, the JIA BIM guidelines offer far more comprehensive coverage.The Architectural Institute of Japan published the Standard Process Map for BIM Project in 2015.Application of Building Information Modeling (BIM) by contractors and builders in Japan is an area of focus for the Japan Federation of Construction Contractors (JFCC) (Baik, 2020).Encouragement of Construction BIM: A Startup Guide was published in November 2017 as a summary of construction BIM publications to date in Japan.The overview illustrates the use of building information modeling (BIM) in actual building projects.Despite the availability of many BIM protocols in Japan, adoption has been gradual.In order to increase the use of building information modeling in building projects, an industry-wide BIM Protocol based on dynamic information sharing has to be created (Baik, 2020; Paul, 2020).

- **France**

The French government commissioned a construction industry R&D initiative in 2014 called MINnD to create BIM standards for infrastructure projects.The government also decided that year to build 500,000 homes with BIM by 2017 (Constructibletrimble., 2022).The European Union allotted €20 million to the digitization of the construction industry in 2015.The program was rolled out as a part of the federal government's Digital Transition Plan for the building sector.France took it a step further in 2017 by making BIM mandatory for all government projects (Bimaplus, 2022).As part of France's plan to digitize the building sector, the country's official standardized roadmap was released to the public in April of 2017(Baik, 2020; Constructible Trimble., 2022)..Enhancing data quality during interchange, meeting timelines, and decreasing total project costs are all goals (Paul, 2020;Constructibletrimble., 2022).

- **Norway**

Norway is among the front-runners in this regard.Norway has already established guidelines or mandates for the use of BIM in the public sector.It has been using the 3D portion of BIM on public projects for at least a decade and is an active participant in the creation of openBIM standards.The Nordic countries are also making headway on automating construction approval and planning permit systems, à la Singapore (Bimaplus, 2022 ; Paul, 2020).

- **India**

As it relates to the implementation of BIM, the adage "better late than never" is appropriate for India.The fields of Architecture, Engineering, Construction, and Operation (AECO) are the nation's second-largest economic sector.The Indian government is putting more resources into BIM to ensure its success.The government recognizes BIM's potential as a powerful and cost-saving technology, but it has yet to fully integrate it at the design level (India Building Information Modelling Association, 2020).BIM has widespread support from both the government and industry (Sacks et al., 2018).

One of the most prominent examples of the use of 5D BIM technology in public sector projects is the Nagpur Metro Rail Project.The level of education regarding BIM in the country has risen in recent years.Customers and the building industry alike are aware that BIM may reveal even the most minute details of a project's execution.The country, however, has to increase its degree of awareness.Customers are mostly from the design and engineering industries (Paul, 2020).

- **Netherlands**

In the Netherlands, BIM adoption is at an all-time high in the architecture, engineering, and construction sectors.The Netherlands has one of the highest BIM adoption rates in the world because of the widespread demand from big public clients (such as the Central Government Real Estate Agency) to utilize BIM.The ability of BIM systems to communicate and share information is facilitated by the widespread use of a variety of open protocols (or standards) for procedures, data formats, and/or semantics.The VISI protocol was developed in the Netherlands and is now widely used as the foundation for collaboration and information sharing among construction professionals.In the context of systems engineering, the term "COINS" (Constructive Objects and the INtegration of processes and systems) refers to a Dutch integrated, complementary standard for transferring digital information.CB-NL, or the Connected Buildings Netherlands Standard, is a protocol for linking digital collections of architectural elements ((Underwood & Isikdag, 2009; Paul, 2020).

Rijkswaterstaat, the Dutch General Directorate for Public Works and Water Management, is responsible for the planning, building, management, and upkeep of the country's primary infrastructure facilities and is one of the largest public clients in Europe when it comes to the use of building information modeling (BIM).With the official definition of BIM as "Better Information Management," the government agency is preparing the groundwork for the use of openBIM standards across all infrastructure projects in Europe (Paul, 2020; Underwood & Isikdag, 2009).

- **Australia**

Australia's transportation and infrastructure agencies used the phrase "digital engineering" to describe the BIM initiative's focus on physical structures.Here, BIM implementation varies widely and is very dispersed.The relatively tiny continent is taking a technologically advanced look at BIM's finer points.Some of our private-sector customers are treating BIM as "business as usual," which means they are accelerating their pace of technology adoption.Norms such as PAS1192-2 are serving as a foundation for implementation in the public sector.Nonetheless, the adoption is falling apart due to a lack of expertise and people's tendency to operate in silos.The Australian government is also involved in this.Each division operates independently of the others, each with its own procedures and methods.This leads to ambiguity in the supply chain as businesses try to make sense of the varying regulations imposed by various government agencies and the information they demand.Because of the lack of a universally accepted system for assessing development, both public and private sector customers are looking to the United Kingdom for help (BSI, 2020; Paul, 2020).

- **China**

China is making great strides in BIM, but they still have a long way to go. When MOHURD's predecessor, the Ministry of Construction, presented Basic Points of Informatization Work in the Construction Field in 2001 as part of the country's 12th Five-Year plan, China's BIM information expedition got underway (Liu et al., 2017; Guan & Huang, 2020). The initial uptake was low because this was only a suggestion and not a requirement. The Ministry of Housing and Urban Development (MOHURD) has since released its thirteenth five-year plan, which covers the years 2016 through 2020.The goal is to have a survey and design firm, premium and class building construction firm that has mastered and realized BIM's integrated application with enterprise management system and other information technologies by the end of 2020.But Hong Kong is light years ahead in its use of BIM. Training for the UK's Level 2 Standards is being offered by a growing number of government agencies here (Abbas et al., 2019; Paul, 2020).

- **Brazil**

Brazil will require BIM adoption as part of a national program guided by a BIM roadmap.In June 2017, Brazil formed a Strategic Committee for the Implementation of BIM (CE-BIM) and a Technical Support Group (CAT-BIM).The committee included six subcommittees that dealt with issues such as standards and regulation, infrastructure and technology, the BIM platform, public procurement, human resource development, and information dissemination. While building information modeling (BIM) is not yet mandated at any level, research from a local BIM consultant and industry reports such as McGraw Gill Construction's "The Business Value of BIM for Construction in Major Global Markets" (2013) show that BIM adoption is far along among contractors in Brazil (34 out of a total of 40 contractors).According to the same survey, the primary goal of building information modeling (BIM) in Brazil is not cooperation with owners but rather cost containment throughout the construction process (Paul, 2020).

- **Austria**

In 2015, Austria first adopted BIM standards, and in the intervening years, ASI (Austrian Standards) has produced a set of guidelines for the widespread use of BIM.The newest addition to the Austrian market is the A 6241.2, which ushers in BIM Level 3 for the country.Unfortunately, adoption is occurring slower than hoped.Today, there is a dearth of both BIM-capable contractors and BIM coordinators (Austrian-standards, 2021; Paul, 2020).

- **Italy**

The Italian Ministry of Infrastructure has unveiled a preliminary strategy to make BIM obligatory beginning in 2019.However, this would only be necessary for projects with a budget exceeding $100,000,000.If all goes according to this preliminary plan, the country should witness complete implementation by 2022.When this happens, using BIM on government projects is a must.However, traditional methods will still be used for smaller projects like residential structures that don't need extra protection.In general, the EU is becoming more open to using BIM.There are several forces pushing forward with a digital agenda for infrastructure.Some of them are even looking to the United Kingdom for help to ensure that their building industry is prepared for the future (Paul, 2020).

- **Singapore**

Singapore recognizes BIM as an important technology that will help it become a smart nation.That's why the BCA and buildingSMART Singapore are pushing BIM so hard in the building trades.The Building Sector Model (BIM) Roadmap was created by BCA in 2010 with the lofty goal of having 80% of the construction industry utilize BIM by 2015.The success of this initiative was contingent on the need for all architectural and engineering designs to be submitted electronically in the BIM format for governmental review and approval.The government of Singapore, acting through the BCA, has placed a recent emphasis on construction productivity and launched a Construction Productivity Roadmap to radically alter the sector and significantly increase productivity.Increasing BIM usage is viewed as a priority because of its potential to boost productivity in the building industry (Tüv Süd's, 2020).The BCA developed a second roadmap to encourage BIM coordination across the whole digital building process.The goal of the new training program at all levels is to make learning about VDC fun and engaging through the use of real-world examples and practical exercises.The primary emphasis of the road plan is BIM's potential in facility management and smart city applications (Paul, 2020).

- **Europian Union**

There has been significant progress towards BIM deployment throughout Europe.Businesses, universities, and the government are all showing a strong interest in the technology.They are eager to learn about BIM adoption in other regions so that they may get a well-rounded understanding of the concept and apply the best practices they find there to their own country's BIM program.Several goals, regulations, and national policies are put out with the hope of swaying experts to adopt digitalization within the sector and adopt a uniform BIM vocabulary. Europe's governments are doing an excellent job of facilitating cross-border cooperation and standardizing common norms, two factors that are crucial to the region's economic success (Charef et al., 2019). The European Union (EU) BIM Task Group was formed in 2016 with the goal of creating a world-class digital construction sector. This group was formed to coordinate the many efforts being made at the national level into a unified, coordinated European strategy. The mission of the European Union's Building Information Modeling Task Force was to "deliver a common European network aimed at aligning the use of building information modeling in public works. "Exciting new breakthroughs in the spread of BIM across the continent have resulted from the group's creation. The rate at which various nations are progressing varies (Paul, 2020; Charef et al., 2019).

- **Spain**

In Spain, BIM use is voluntary rather than required at this time.EU Directive 2014/24/UE has, nevertheless, also applied to the Spanish building industry.According to this directive, member states are encouraged and required to utilize BIM in 2016 for building projects using EU public funding.The "BIM Commision" was established in 2015 by the Ministerio de Fomento (Ministry of Development) to produce a strategy for introducing the BIM methodology in Spain (Trace Software, 2020).A long-term plan for introducing BIM has been developed (Zangróniz Hernán, 2021). Beginning in December 2018, and continuing through July 2019, the use of BIM is expected to be mandated for all publicly funded construction and infrastructure projects (Trace Software, 2020; Paul, 2020).

- **The United Kingdom**

The United Kingdom (UK) currently has the most ambitious and radical BIM strategy in the world, with the stated goal of improving the UK's international reputation for its designers, contractors, and product manufacturers in order to attract more international business, thereby resulting in economic growth and job creation.There is no way to participate in any UK government project unless you meet BIM Level 2 standards.You can only guess how popular BIM is in the UK (DJBH Global, 2022).The United Kingdom is at a tipping point when it may utilize its domestic program's success and assume a worldwide leadership position in the use of building information modeling (BIM), the provision of building information modeling services, and the creation of building information modeling standards.The government's encouragement of BIM has hastened its spread. In April 2016, the British government enforced the use of Building Information Modeling (BIM) in all building projects that receive central government funding.Adoption rates of building information modeling (BIM) have increased since the mandate's implementation.

The National BIM Report 2018 reveals that, following the 2016 mandate, 20% of the sector has embraced BIM.Almost three-quarters now make use of BIM, up 12 percentage points over the previous year and the largest annual gain since 2014.There is no longer a company too large or too small to benefit from BIM; the importance of the methodology has spread throughout the business world.Compared to larger firms, smaller ones are less likely to use building information modeling (BIM).The research found that 82% of small practices (1–15 employees) and 78% of big practices (51+ employees) have used BIM.But despite this, two-thirds of smaller firms (those with 15 employees or fewer) claim to have implemented BIM.The potential advantages of BIM appear to be there for businesses of all sizes.Eighty percent of healthcare and educational facility design firms utilize building information modeling (BIM), with another eighty-three percent using it for "mixed-use" projects.Sixty-seven percent of firms that specialize in "one-off new houses, extensions, conversions, or alterations" have implemented BIM.Here, BIM is used in all settings, not simply by major firms or for particularly complicated projects (DJBH Global, 2022; Paul, 2020).

3.1. Adoption in African Continent

Many nations have already established fundamental strategies toward the implementation of Building Information Modeling (BIM), such as the creation of common BIM standards and guidelines, which have increased the efficiency of the Architecture, Engineering, and Construction (AEC) industry and driven noticeable optimizations. Recent studies, however, have shown that Africa has the lowest degree of BIM adoption compared to other continents, despite the fact that the AEC business is developing internationally. There has been a much lower rate of BIM (Building Information Modeling) adoption and knowledge of digital construction techniques in Africa compared to other regions and nations. Lack of country-specific BIM Mandates and a general lack of comprehension of the benefits that BIM provides to the wider construction sector are mostly to blame for the poor acceptance of BIM within the AECO (Architecture, Engineering, Construction, and Operation) business in Africa(Bimafrica.org/, 2022).

3.1.1. The challenges of adopting BIM in Africa

Building information modeling (BIM) has significant barriers to adoption across the African continent, including but not limited to the following:

3.1.2. Lack of professionals and training:

Organizations and academic institutions provide short-term training and conferences as a substitute for long-term solutions to the industry's lack of skilled experts (i.e., BIM-compliant graduates).

4. The Government's Lack of Support for BIM

Most African countries' governments do not actively promote BIM. Some government agencies in Ethiopia, Morocco, and Egypt, however, have begun developing plans.

- **Cost:**

In a continent where most businesses are Small and Medium Enterprises (SMEs), the high cost of implementing BIM remains a significant barrier for SMEs.

- **Absence of a contractual framework**

In many cases, the implementation of BIM is hindered by the fact that existing contractual frameworks are not adapted to the rapidity with which technology is advancing.

- **Lack of client demand**

Lack of government backing has a crippling effect on demand because governments are often the largest clients in the AEC business in most nations. Universities in the area have not explicitly included BIM studies in their curriculums, unlike in other areas of the world, where digitalization and building information modeling (BIM) courses (together with open building SMART standards) are required for many construction-related majors.

- **Strategies for Overcoming the BIM Implementation Challenges**

Building Information Modeling (BIM) research ought to be given a greater emphasis at academic institutions. For the purpose of increasing awareness among the necessary stakeholders, workshops focusing on the benefits of BIM should be organized. Utilizing Collaborative Procurement Systems will assist in providing support for Building Information Modeling. Creating legal documents outlining who owns the intellectual property associated with BIM technology and establishing a solid foundation for BIM technologies. The usage of BIM needs to be mandated by the government as a condition for any construction industry purchase. Develop models for insurance coverage that will cover BIM equipment. Disseminate to all parties involved the lessons you've gained from participating in the pilot programs. increase the number of projects in the business sector that make use of BIM. increase the level of BIM's process efficiency. Carry out proof-of-concept projects to demonstrate that BIM can produce the desired results. To achieve a deeper level of integration between BIM software and existing systems, Employ Building Information Modeling, often known as BIM, as a pedagogical tool in all areas of study that are connected to the built environment. Make the move from traditional approaches to BIM as smooth and functional as possible. Efforts should be made to make BIM software more accessible. Establishing rules for the execution of projects using the Building Information Model can be a helpful step in ensuring the effective adoption of Building Information Modeling (BIM). Government agencies should be made aware of the benefits of "model-based" outputs, and they should be instructed on how to apply these outputs.

5. Conclusions

According to the research that has been conducted, the use of BIM would be beneficial to the construction industry on a worldwide scale if it were more widely adopted and implemented. According to the study that has already been done, this change will be accompanied by its own unique set of difficulties, which runs counter to what one may anticipate to be the case. It has been decided that the lack of progress in putting BIM technology to use can be blamed on either problem with managing human resources (which are the fault of professionals) or problems with managing contracts. In the absence of prompt response, these challenges will prevent BIM from gaining widespread adoption. Also, the different players in the construction industry need to come up with ways to get rid of or at least greatly reduce the effects of the problems that have been identified.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Authors' Contribution Statement

Authors 1 and 2 conceived of the research, sourced the articles necessary for the completion of this work, and performed analysis. Authors 3 and 4 created the study's design and conducted the literature review; and Authors 5 and 6 proofread and edited the piece for clarity and accuracy.

Declaration of Conflict of Interests

The authors declare no conflict of interest. For the final piece, clearance from an ethics board is unnecessary.

References

[1]. Abbas, R., Behnam, A., Mohsen, K. Prospect of BIM in the land administration domain—Technical aspects. BIM and Urban Land Administration, 2019; 207-220. doi:10.1201/9781351032346-7.

[2]. Ames, J. Adopting new technology when is it time to change? Computer Standards & Interfaces, 1999; 21(2): 150. doi:10.1016/s0920-5489(99)92117-7.

[3]. Anker Jensen, P., and Jóhannesson, EI. Building information modelling in Denmark and Iceland. Engineering, Construction and Architectural Management, 2013; 20(1): 99-110. doi:10.1108/09699981311288709.

[4]. Aramesh, M., Kasaeian, A., Pourfayaz, F., and Wen, D. Energy analysis and shadow modeling of a rectangular type salt gradient solar pond. Solar Energy, 2017; 146: 161-171. doi: 10.1016/j.solener.2017.02.026.

[5]. Arayici, Y., Counsell, J., Mahdjoubi, L., Nagy, GA., Hawas, S., and Dweidar, K. Heritage building information modelling. Taylor & Francis, 2017.

[6]. Atazadeh, B., Kalantari, M., Rajabifard, A., Ho, S., and Ngo, T. Building information modelling for high-rise land administration. Transactions in GIS, 2016; 21(1): 91-113. doi:10.1111/tgis.12199.

[7]. Austrian-standards. Building information modeling (BIM). Austrian Standards. Last modified 2021. https://www.austrian-standards.at/en/topics/construction-real-estate/building-information-modelling-bim.

[8]. Baik, A. Review of UNESCO's world heritage nomination files (WHNF), building information modelling (BIM) and heritage building information modelling (HBIM). Heritage Building Information Modelling for Implementing UNESCO Procedures, 2020; 12-54. doi:10.1201/9781003036548-2.

[9]. Baik, A., and Boehm, J. Jeddah heritage building information modelling (JHBIM). Heritage Building Information Modelling, 2017; 132-153. doi:10.4324/9781315628011-11.

[10]. Bimafrica.org/. African BIM report 2022. BIM Africa. Last modified February 28, 2022. https://bimafrica.org/abr2020/.

[11]. Bimaplus. BIM A+ European Master Course. https://bimaplus.org/. Last modified July 22, 2022. https://bimaplus.org/.

[12]. Blömer, D. Benefits of building information modeling (BIM) for construction project management in Germany. 2016.

[13]. BSI. BIM - Building information modelling. Standards, Training, Testing, Assessment and Certification | SI. Last modified 2020. https://www.bsigroup.com/en-AU/Building-Information-Modelling-BIM/.

[14]. Burry, M. BIM and MetaBIM: Design narrative and modeling building information. Building Information Modeling, 2015; 349-362. doi:10.1002/9781119174752.ch26.

[15]. Carpino, C., E. Loukou, P. Heiselberg, and N. Arcuri. undefined. Building Research & Information, 2020; 48(8): 899-921. doi:10.1080/09613218.2019.1707639.

[16]. Charef, R., S. Emmitt, H. Alaka, and F. Fouchal. Building information modelling adoption in the European Union: An overview. Journal of Building Engineering, 2019; 25: 100777. doi: 10.1016/j.jobe.2019.100777.

[17]. Chen, W. Integration of building information modeling and Internet of things for facility maintenance management. 2019. doi:10.14711/thesis-991012711065803412.

[18]. Clarke, J. Energy simulation in building design. Routledge, 2007.

[19]. Constructibletrimble. This is how the French are adopting BIM [Interview]. Construction Industry Data | Construction Industry Resources & News. Last modified October 13, 2022. https://constructible.trimble.com/construction-industry/this-is-how-the-french-are-adopting-bim.

[20]. DJBH Global. BIM services. DJBH Global – BIM Manpower & Services Consultant. Last modified 2022. https://djbhglobal.space/bim-services/.

[21]. Douglass, C., and J. Leake. Energy efficient design using building information modeling and energy simulation. 2011 ASEE Annual Conference & Exposition Proceedings, 2019; doi:10.18260/1-2--17845.

[22]. Du, Z. A BIM-based framework for safety management in the building construction project. 2019; doi:10.14264/uql.2018.457.

[23]. Eastman, C., P. Teicholz, R. Sacks, and K. Liston. BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. John Wiley & Sons, 2011.

[24]. Emmanuel Di Giacomo. BIM, trends from all around the world. Enjoy free comfortable tools to publish, exchange, and share any kind of documents online. Last modified 2015; https://docplayer.net/34902540-Bim-trends-from-all-around-the-world.html.

[25]. Eschenbruch, K., and J. L. Bodden. Integrating BIM in construction contracts. Building Information Modeling, 2018; 303-314. doi:10.1007/978-3-319-92862-3_17.

[26]. Excelize. 5 benefits of BIM adoption and implementation in USA. BIM, MEP Services Outsourcing Company | India, USA, UK, Australia, UAE. Last modified 2021. https://excelize.com/blog/5-examples-of-bim-adoption-in-usa-that-demonstrate-clear-benefits.

[27]. Fernando, T. Future collaborative workspaces for the construction industry. Virtual Futures for Design, Construction & Procurement, 2009; 278-289. doi:10.1002/9781444302349.ch20.

[28]. Ghanim F. Complicities between industrialized building systems and building information modeling. Research Companion to Building Information Modeling, 2022; doi:10.4337/9781839105524.00027.

[29]. Guan, Y., and Z. Huang. Evaluation of the effect of new health reform policy of China based on prospect theory. 2020; doi:10.21203/rs.3.rs-16835/v1.

[30]. Gundu, T., and N. Modiba. Building competitive advantage from Ubuntu: An African information security awareness model. Proceedings of the 6th International Conference on Information Systems Security and Privacy, 2020; doi:10.5220/0008983305690576.

[31]. Haider, S., and I. Hafeez. A step toward smart city and green transportation: Eco-friendly waste PET management to enhance adhesion properties of asphalt mixture. Construction and Building Materials, 2021; 304: 124702. doi: 10.1016/j.conbuildmat.2021.124702.

[32]. Halmetoja, E., and N. Lepkova. Utilising building information models in facility maintenance and operations. Teknik Dergi, 2022; doi:10.18400/tekderg.748397.

[33]. Henderson, H. Encyclopedia of computer science and technology. Infobase Publishing, 2009.

[34]. Huang, K. W. Application of BIM in project management. Applied Mechanics and Materials, 2014; 496-500: 2836-2839. doi:10.4028/www.scientific.net/amm.496-500.2836.

[35]. India Building Information Modelling Association. India Building Information Modelling Association (R.). IBIMA. Last modified 2020. https://www.ibima.co.in/.

[36]. Ismail, N. A. Construction cost estimating incorporating building information modelling (BIM) in the Malaysian construction industry. 2021; doi: 10.5204/thesis.eprints.116646.

[37]. Jain, K., K. Khoshelham, X. Zhu, and A. Tiwari. Proceedings of UASG 2019: Unmanned aerial system in Geomatics. Springer Nature, 2020.

[38]. James F. An integrated model of factors and barriers influencing building information modeling and lean construction adoption. Research Companion to Building Information Modeling, 2022; doi:10.4337/9781839105524.00013.

[39]. James Vandezande. building SMART International. Last modified 2019. https://www.buildingsmart.org/wp-content/uploads/2019/03/Status-of-BIM-Adoption-in-the-US-James-Vandezande.pdf.

[40]. Jodh K. Building information modeling and building automation systems data integration and big data analytics for building energy management. Research Companion to Building Information Modeling, 2022; doi:10.4337/9781839105524.00036.

[41]. Johansson, M., Roupé, M., & Bosch-Sijtsema, P. (2015). Real-time visualization of building information models (BIM). Automation in Construction, 54, 69-82. doi: 10.1016/j.autcon.2015.03.018.

[42]. Kaparaju, P., Howlett, R. J., Littlewood, J., Ekanyake, C., & Vlacic, L. (2018). Sustainability in energy and buildings: Proceedings of the 10th International Conference in Sustainability on Energy and Buildings (SEB'18). Springer.

[43]. Kensek, K., Ding, Y., & Longcore, T. (2016). Green building and biodiversity: Facilitating bird-friendly design with building information models. Journal of Green Building, 11(2), 116-130. doi:10.3992/jgb.11.2.116.1.

[44]. Khosrowshahi, F. (2017). Building information modeling (BIM) a paradigm shift in construction. Building Information Modelling, Building Performance, Design and Smart Construction, 47-64. doi:10.1007/978-3-319-50346-2_4.

[45]. Kibert, C. J. (2016). Sustainable construction: Green building design and delivery. John Wiley & Sons.

[46]. Krygiel, E., & Nies, B. (2008). Green BIM: Successful sustainable design with building information modeling. John Wiley & Sons.

[47]. Kubba, S. (2012). Handbook of green building design and construction: LEED, BREEAM, and green globes. Butterworth-Heinemann.

[48]. Kumar, S. S., & McArthur, J. J. (2015). Streamlining building information model creation using Agile project management. WIT Transactions on The Built Environment, doi:10.2495/bim150201.

[49]. Lach, E. L. (2020). Eckert, J. Presper (9 Apr. 1919–3 June 1995), electrical engineer and computer pioneer. American National Biography Online, doi:10.1093/anb/9780198606697.013.4961.

[50]. Larsson, N. K., & Cole, R. J. (2001). Green building challenge: The development of an idea. Building Research & Information, 29(5), 336-345. doi:10.1080/09613210110063818.

[51]. Liu, B., Wang, M., Zhang, Y., Liu, R., & Wang, A. (2017). Review and prospect of BIM policy in China. IOP Conference Series: Materials Science and Engineering, 245, 022021. doi:10.1088/1757-899x/245/2/022021.

[52]. Liu, J. G., & Mason, P. J. (2016). Image processing and GIS for remote sensing: Techniques and applications. John Wiley & Sons.

[53]. Liu, Q., & Wang, Z. (2021). Green BIM-based study on the green performance of University buildings in northern China. doi:10.21203/rs.3.rs-260952/v1.

[54]. Lu, W., & Anumba, C. (2022). Research companion to building information modeling. Edward Elgar Publishing.

[55]. Lu, W., Lai, C. C., & Tse, T. (2018). Adopting BIM for cost management. BIM and Big Data for Construction Cost Management, 53-74. doi:10.1201/9781351172325-4.

[56]. Maher, M. (2018). Facility operations readiness and project start-up support and integration. Day 2 Wed, October 24, 2018; doi:10.2118/191984-ms.

[57]. Mannino, A., Dejaco, M. C., & Re Cecconi, F. (2021). Building information modelling and Internet of things integration for facility management—Literature review and future needs. Applied Sciences, 11(7), 3062. doi:10.3390/app11073062.

[58]. Manouchehri, M., Valiente López, M., & Santiago López, J. (2022). BIM technology in green buildings: Integrating BIM with greenery systems. Lecture Notes in Civil Engineering, 141-166. doi:10.1007/978-981-19-1894-0_9.

[59]. Martens, B. (2015). BIM and virtual reconstruction: A long-term view of (re-)modeling. Building Information Modeling, 251-265. doi:10.1002/9781119174752.ch19.

[60]. Maskil-Leitan, R., Gurevich, U., & Reychav, I. (2020). BIM management measure for an effective green building project. Buildings, 10(9), 147. doi:10.3390/buildings10090147.

[61]. Mike, D. (2022). Building information modeling, smart construction objects, and pervasive technologies integration. Research Companion to Building Information Modeling. doi:10.4337/9781839105524.00024.

[62]. Mogbo, O., Sunday, O., & Michael, T. (2018). Determination of the Efficacy of Civilsoft Quick Series in the Design of Reinforced Cement Concrete. A Case study of the Design of a Seven Panel Single storey Building. International Research Journal of Engineering and Technology, 5(6).

[63]. Moshtaghian, F., & Noorzai, E. (2022). Integration of risk management within the building information modeling (BIM) framework. Engineering, Construction and Architectural Management. doi:10.1108/ecam-04-2021-0327.

[64]. Mukherji, P. T. (2011). Study of possible applications of currently available building information modeling tools for the analysis of initial costs and energy costs for performing life cycle cost analysis.

[65]. Nguyen, D. D. (2020). Modeling and reconfiguration of solar photovoltaic arrays under non-uniform shadow conditions. doi:10.17760/d10018682.

[66]. Näser, P., & Wickenhagen, N. (2018). wt Werkstattstechnik online, 108(04), 245-250. doi:10.37544/1436-4980-2018-04-51.

[67]. Ofluoglu, S., Ozener, O. O., & Isikdag, U. (2020). Advances in building information modeling: First eurasian BIM forum, EBF 2019, Istanbul, Turkey, May 31, 2019, revised selected papers. Springer Nature.

[68]. O'Malley, A. (2022, June 28). BIM in the US: Overview of a game changing technology. PlanRadar. Retrieved from https://www.planradar.com/us/bim-in-the-us/.

[69]. Owen, J. (2021). Procurement and construction methods. Self-build, 193-209. doi:10.4324/9781003231257-9.

[70]. Paul, S. (2020, September 17). BIM adoption around the world: How good are we? Geospatial World. Retrieved from https://www.geospatialworld.net/article/bim-adoption-around-the-world-how-good-are-we/.

[71]. Pruyt, E. (2015). From building a model to adaptive robust decision making using systems modeling. Policy Practice and Digital Science, 75-93. doi:10.

[72]. Quan, Q. (2021). Application of BIM technology in modern construction project management. Foreign Language Science and Technology Journal Database Engineering Technology. doi:10.47939/et.v2i3.74.

[73]. Race, S. (2019). BIM within the project. BIM Demystified, 61-62. doi:10.4324/9780429347627-6.

[74]. Deutsch, R. (2019). What you adopt when adopting BIM. BIM and Integrated Design, 3-28. doi: 10.1002/9781119572640.ch1.

[75]. Rasys, E., Hodds, M., Dawood, N., & Kassem, M. (2014). A Web3D enabled information integration framework for facility management. Australasian Journal of Construction Economics and Building - Conference Series, 2(1), 1. doi:10.5130/ajceb-cs.v2i1.3763.

[76]. Rell, K. (2022). Building information modeling adoption and localization. Research Companion to Building Information Modeling. doi:10.4337/9781839105524.00014.

[77]. Reyna, F. (2022). Dynamic-building information modeling workbench for lownet zero energy buildings. Research Companion to Building Information Modeling. doi:10.4337/9781839105524.00035.

[78]. Rohena, R. (2019). Building information management (BIM) implementation in naval construction. doi:10.31390/gradschool_theses.3104.

[79]. Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers. John Wiley & Sons.

[80]. Sacks, R., Korb, S., & Barak, R. (2017). Virtual design and construction. Building Lean, Building BIM, 130-164. doi:10.1201/9781315300511-11.

[81]. Sun, Q., Turkan, Y., & Fischer, E. (2022). Integrating 4D BIM and FDS to simulate and assess fires in buildings under construction. Construction Research Congress 2022. doi:10.1061/9780784483961.102.

[82]. Tian, B., & Liu, K. (2014). Service-oriented approach to facility management using extended building information modelling. ICCREM 2014. doi:10.1061/9780784413777.178.

[83]. Trace Software. (2020, February 28). The implementation of BIM in Spain. Trace Software. Retrieved from https://www.trace-software.com/blog/the-implementation-of-bim-in-spain/

[84]. Tüv Süd's. (2020). Just a moment... https://www.tuvsud.com/en-sg/industries/real-estate/buildings/building-information-modeling.

[85]. Underwood, J., & Isikdag, U. (2009). Handbook of research on building information modeling and construction informatics: Concepts and technologies: Concepts and technologies. IGI Global.

[86]. Valinejadshoubi, M., & Bagchi, A. (2015). Application of BIM concept in the design of energy-efficient buildings. LAP Lambert Academic Publishing.

[87]. Watt, R. (2015). Building information modelling: A study into the suitability of BIM within projects with construction values of less than £5M. WIT Transactions on The Built Environment. doi:10.2495/bim150271.

[88]. Wen, P. (2021). Application advantages of BIM technology in curtain wall project management. Foreign Language Science and Technology Journal Database Engineering Technology. doi:10.47939/et.v2i12.233.

[89]. Wildenauer, A. A., Basl, J., & Poór, P. (2022). Digital transformation framework for facility management based on building information modelling. doi:10.20944/preprints2022.07.0020.v1.

[90]. Williams, B., Haines, B., Roper, K., & Yang, E. (2019). Building information modelling (BIM) for facility management (FM): Industry survey of building assets. Journal of Facility Management Education and Research, 3(1), 18-26. doi:10.22361/jfmer/112195.

[91]. Wu, P., H L., & Wang, X. (2017). Integrated building information modelling. Bentham Science Publishers.

[92]. Zangróniz Hernán, J. (2021). La implantacíon de BIM en Espana = the implementation of bim in Spain. Building & Management, 4(1), 4. doi:10.20868/bma.2020.1.4661.

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