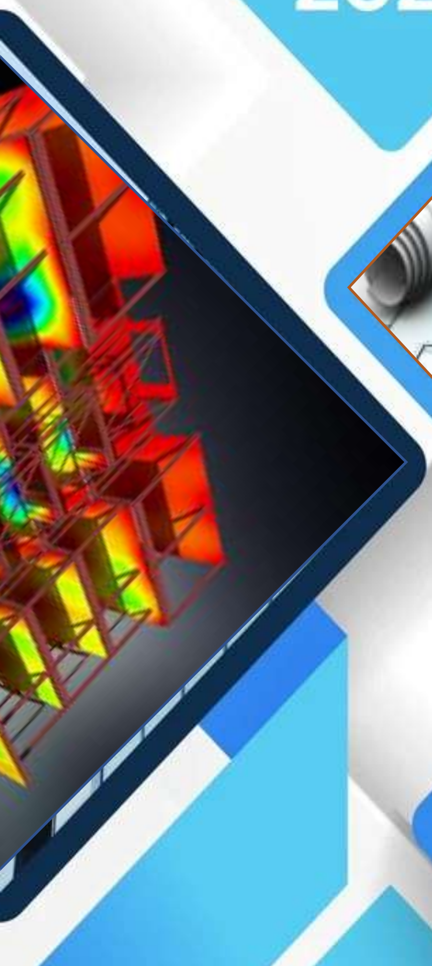
BIM

Building Information Modeling

2025



Prepared by

Dr GUECHI Imen

Foreword

In recent decades, the field of architecture has undergone a profound transformation with the rise of digital technologies in design, planning, and project management. Among these innovations, **Building Information Modeling (BIM)** has emerged as a fundamental tool in contemporary professional practice. This shift goes far beyond software it redefines how we design, collaborate, and build.

This course material is designed for **third-year architecture students** and aims to provide a solid, structured foundation in BIM through progressive and practical content. Rather than simply introducing tools, this document explores their purpose, context of use, and real-world impact on architectural and urban projects.

Across five chapters, the content begins with the historical evolution of design tools from manual drawing to BIM before addressing documentation and project coordination challenges. It then explores the software and platforms used in modern BIM workflows, followed by an in-depth look at **simulation types within Revit**, and concludes by expanding the discussion to the urban scale through **CIM (City Information Modeling)**.

The dual objective of this material is to help students understand the theoretical and technical foundations of BIM, while also equipping them with the practical knowledge to apply these concepts in real-world professional contexts, through examples, case studies, and best practices.

We hope this educational resource will support your development of autonomy, critical thinking, and the ability to integrate advanced digital tools into your future architectural practice.

Table of contents

List of photos

Chapter 01: Evolution of Design Tools: From Paper to BIM

1. Introduction

On the transition from paper to BIM tools and its impacts on architectural practices. In the contemporary scenario, where everything is digitized, the development of technology does not ignore the industry. Architecture, which is the base of urban life and where individual daily life overlaps with it, sovereign to technology. Since the first design production of the first buildings, architectural design processes have existed, but over time, tools and software in this process are reinventing themselves in line with developing technology. With this change, two different eras are left behind. Transition to advanced BIM tools is being experienced from the first architectural production through paper tools. In general, this deep transformation in tools is an opportunity to observe the equal transition in architecture style and understanding. For this reason, the architectural design profession, the ever-increasing developing software, is now investigated with the thesis that the effect on architecture style and understanding will be handled over time.

Building Information Modeling (BIM) tools are at a point in the professional lives of many architects for a long time. Having many steps of architectural design, such as 2D drawing, 3D visualization, schedule details, and costing, all of them in a complete digital design model, is the biggest contribution to architectural practices. However, in order for this approach to be applied very well and integrated as it is desired, the basis of architectural design, the foundations laid with pen on paper are coming into question for its damages. The biggest drawback is the breaking of the creative atmosphere of the architect. Working on paper, sketching or modeling, changing the tool without narrowing the stream of thought arises various figures of thoughts. However, the difficulty of moving a printed or modeled creative idea with a digital pen is slowing down the creative process (Coates et al., 2018). This creative aura of BIM tools, the increase in results due to the speed and the sharp increase in the BIM use of architects can even be felt at the limit of the threat to all trades of architecture. This situation, on the one hand, remains on paper by hiring itself and software animations, on the other hand, is on the lookout for desktop 3D Printers. However, it is not possible for them to compete at the same time with their changes and quickness.

2. Historical Overview of Architectural Design Tools

In the beginning, ancient architects made sketches of buildings. The Greeks introduced the first written plans, showing the location of temples, roads, and the town boundary, designed with experience. Post sun and sun dial were used to measure time for planning. The Roman city layout was designed using two crossed roads equipped with pens and compasses. The great master of the Renaissance period, Leon Battista Alberti, wrote the first treatise “De Re Aedificatoria”. He introduces construction law. Every architectural object must be interfaced and mathematically perfect. The view with a single vanishing point was used for creating perspective. The geometry was using compasses, black pens, and simple math like golden cut or the theory of harmonious proportions began to appear.

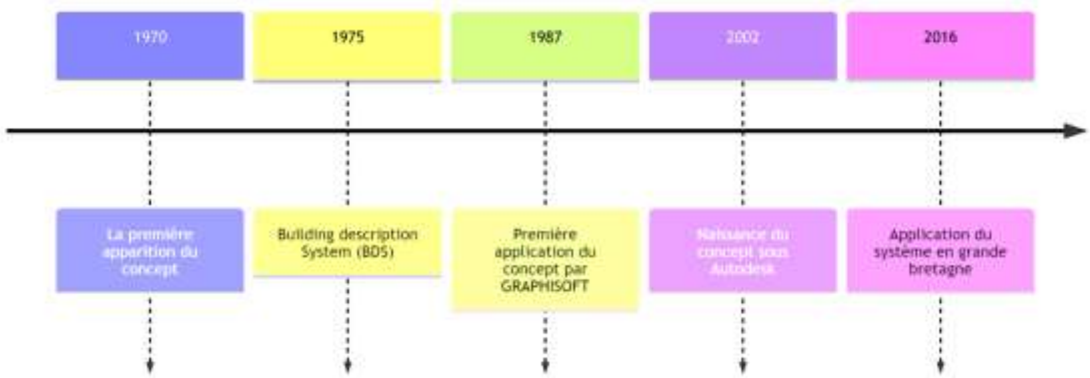


Figure 01: The history of the concept

After paper and drawing tools became more popular, the first libraries with readymade graphic drawings were created. Rudimentary local building traditions began to use these resources for implementation. Despite this, the City Council’s competition for reconstructing the city of L’Aquila, damaged by a devastating earthquake in Italy, failed 29 times when buildings began. As a result, the quarries were closed until there was enough experience to design. The world’s first detailed plan was the fortification of Mars, created by a combination of topographic survey and geometric tools in a geometric plan that amazed most architects of the time. Until printing, the best draftsmen of the time gathered and redesigned the walls of the most famous bastilles of the time according to the rules of the trace geometric art. After the invention, Leonard and his well-known metal engraver created the most recognized drawings of fortified lairs through mass media. Despite this, realistic implementation faced limitations which were only permissible at risk and were forbidden in countries at war. Old drawings cannot be accurately adapted to the local features of the terrain, as was customary practice in making small corrections. In such a devastated landscape as in Italy after the earthquake or during the siege of the fortress, the rule of this procedure is lost. Only one copy of the complete version of drawing has been found in archives anywhere in the world, where the cavalleria farm in a poor building frame of a villa was partially measured. This document reveals how the drawings were read. However, even drawings of one licensed villa completely failed to establish the skeleton of the object. Rear axle shells are completely violated on the terrain. Subsequent surveys of one half of the estate still overlap with the drawing of the hinge's defensive wall. The geometry of the 16th century was based on one dot and treatment ruler with a compass, articulation for establishing the eighth circle, the restriction for exact geometrical division of each perpendicular circle. And even in such a simple plan, the possible object must be perfectly rounded (Carlos Pérez Sánchez et al., 2017).

3. The Emergence of BIM (Building Information Modeling)

Historically, building design was done on paper, in two dimensions, using plans or visual layouts. Over time, the architect's role became more specialized, and design evolved into a structured process, moving from intention to construction. In recent decades, the architecture, engineering, and construction (AEC) industry has increasingly adopted computer-aided design (CAD), especially with the emergence of object-oriented systems now known as BIM (Building Information Modeling).

BIM is a technology supported by standards and methodologies that enables 3D modeling of the physical and functional characteristics of a building before it is built. Although the foundations of BIM have existed for over 20 years, recent advances in computing have made its use more accessible. BIM is considered a major shift in project delivery, enhancing collaboration compared to traditional communication methods.

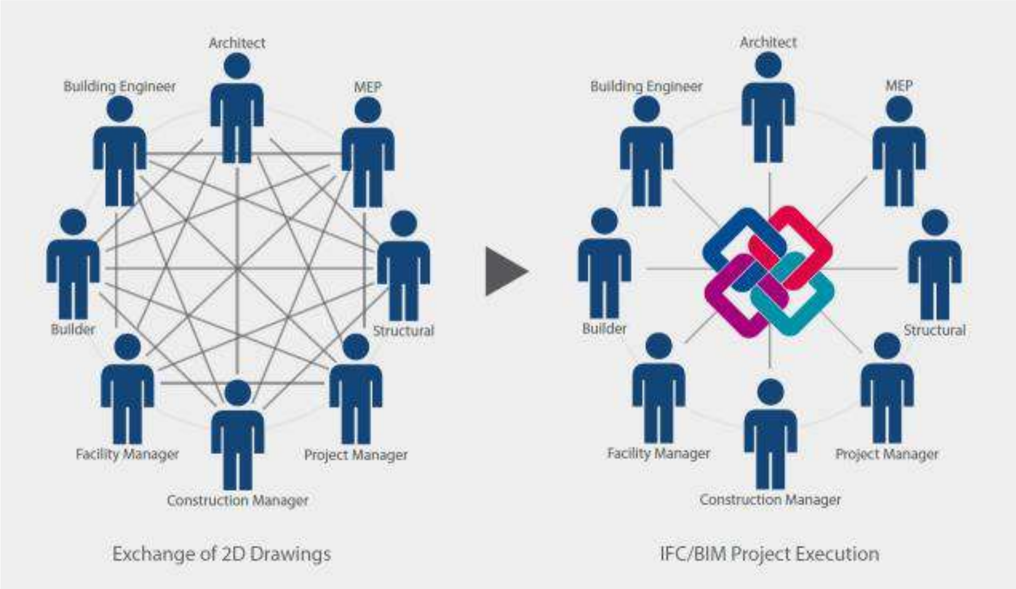


Figure 02: the BIM working method

Unlike 2D CAD, BIM allows for realistic 3D representations where each object is measurable, interactive, and editable. This improves sustainable design by identifying conflicts or inconsistencies early in the process. In addition to graphic modeling, BIM stores useful data for quantity takeoffs, clash detection, energy simulations, sun and shading studies, CO_2 analysis, and more.

BIM also aids documentation, subcontractor coordination, cost estimation, and on-site communication. It is accessible to a wide range of users, both technical and non-technical, and the rich data it contains can help extend the lifecycle of older buildings.

4. Key Differences Between CAD and BIM

As computer-based tools have been increasingly incorporated in architecture, its field has dramatically evolved. In the last two decades, information and communication technologies have had a direct impact on the work of architects and construction professionals, revolutionizing it. Among the few professional figures that are used in the building industry, there is Building Designer, as him/her mostly use the same tools as an architect (Carlos Pérez Sánchez et al., 2017). Among them, the most common ones are Computer-Aided Design (CAD) tools, which help to work on documents and geometry optimization. More recently, Building Information Modeling (BIM) technology has started being used to generate a database of elements and connections between objects, which is enriched over time following the project (Ristevski et al., 2018).

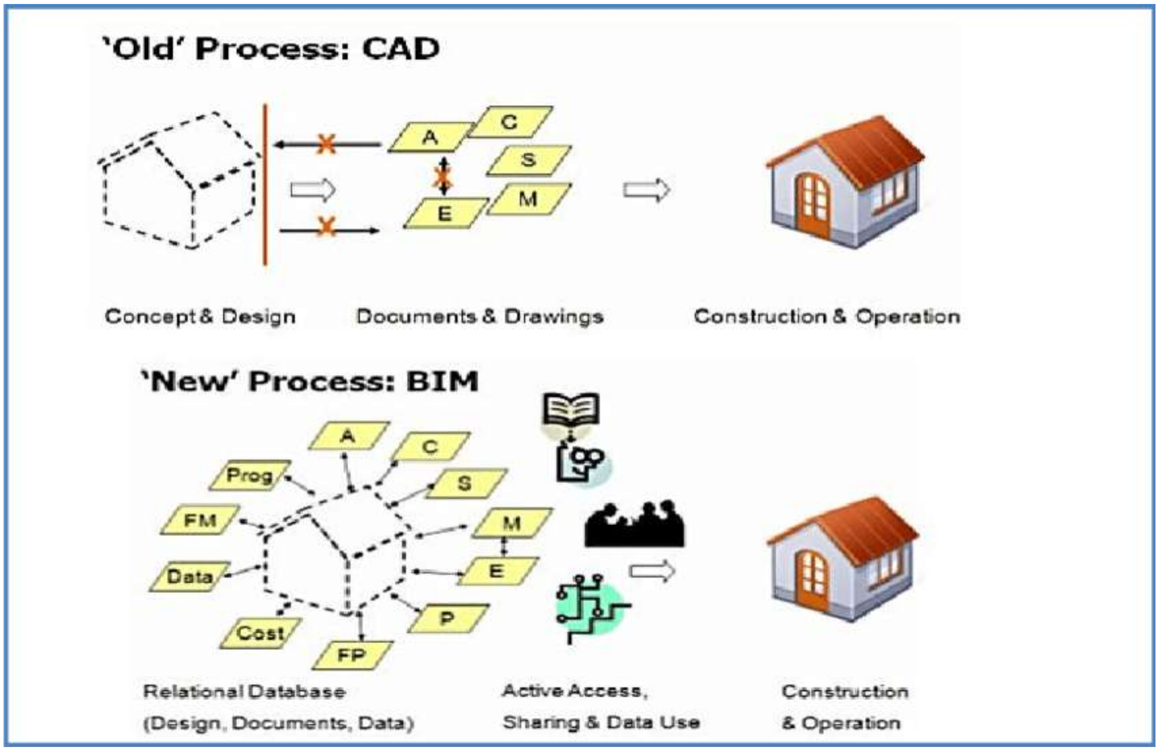


Figure 03: Comparison between Conventional CAD and new BIM Approach

At first glance, CAD and BIM are not that different. They are believed to be the same or at least similar types of tool, but they are not. BIM generates a model that includes a database with a lot of information about the building, and with it, it can optimize its size or cost. CAD generates one or more representations of the geometry of the model, and what is not drawn, it doesn't exist. By drawing it twice, being the second on one of the first sheets of the model, what is drawn increases the probability of ending up being built. In a model generated with a BIM tool, on the other hand, every representation made from a model always shows the same material that can have different thicknesses. It is possible to input possible doubts or information directly on the model, and they are available to everyone. In a CAD model it is not possible, as doubts and the geometry description are separate. The first is written in a document that must be delivered together with the model to understand it, and nobody reads it. If the sections are bad because they contradict the plan, nobody answers why.

5. The Development of BIM Software

The development of BIM software has seen continuous growth, with tools like AutoCAD, Rhino, SketchUp, and more recently Alias becoming essential for architects across different scales and building types. The introduction of laser cutters in the 1980s and 3D printing in the 1990s significantly improved model accuracy. Later, software and scripting tools like Processing, Grasshopper, and Python enabled architects to create parametric models in innovative ways.At the same time, the industry has moved towards more sustainable practices, such as 3D printing using recycled materials and sharing digital content like plans and sections online. IoT (Internet of Things) integration is increasingly common in design processes, with 3D printers serving as an example of this technological evolution.

Figure 04: BIM software list

Standard BIM software like Revit (by Autodesk) supports all project phases from conceptual design to constructionwith high accuracy using parametric components. ArchiCAD (by Graphisoft), released in 1984, allows user-friendly 2D/3D modeling, sections, and unique visualizations like the celery cartoon style. Tools like BIMx, Artlantis (for fast photorealistic rendering), and Dynamo (a coding add-on for Revit) enhance these platforms. Online tools such as A360 and BIM 360 allow file sharing and collaboration across different platforms. Vectorworks' Marionette, inspired by Grasshopper, enables flexible parametric workflows.

Choosing the right BIM software depends on factors such as total cost (hardware, licensing, training), project scale, sector, and client needs. Revit and ArchiCAD, while powerful, are expensive and may require high-performance computers. However, most offer free versions for students and educational institutions. Revit was released in 2000 after 8 years of development, followed by ArchiCAD in 2002. Older software like Microstation has updated its tools to stay competitive, while BIM+, the latest innovation, is disrupting the market with faster and more accessible augmented models.

5.1. Revit

Building Information Modeling (BIM) technology has had a profound effect on the way architectural design is undertaken. BIM is to CAD as CAD was to hand drafting. Its introduction has shifted the design paradigm from output driven practices to real time computer modeling that makes design decisions based on changes to model geometry and associated data in ways only imaginable in science fiction until recently. The majority of practices now use BIM software as the primary design tool at the earliest stages in design development to navigate briefings, construct massing studies, interrogate access for disabled people, and generate high quality renderings to impress clients. The digital nature of BIM means that design is no longer restricted to being printed on paper. Real-time collaborative software allows multiple team members at different locations to be in the same model at the same time altering, testing, and building up the design. Functions traditionally performed in house have been, and will continue to be, outsourced to specialized companies offshore that work from exported models (Anton Kivits & Furneaux, 2013).

At project delivery stage, designs are often massaged to seamlessly drop into site conditions creating impossible geometric articulations in the so-called “as built” plans. Yet the ubiquity of BIM models of existing conditions that can be bought or commissioned has started a trend where clients and consultants snap shot competitive stages of projects to document if unfair conditionals change claims. This has happened in the first world for some years but is beginning to hit parts of the market in other parts of the world. Revit is unique among BIM softwares in that it was the first to market itself and bill itself as a BIM software and has held steadily onto 70% – 80% market share for over a decade. Revit is a parametric modeling software with which components (families) are altered, linked and built to generate and co-create complex 3D environments. It has an extensive library that includes architecture specific components that can be easily downloaded from manufacturers websites and shared online. The transfer from CAD to Revit often leads to inefficiencies at the start of an office-wide implementation as staff navigate the learning curve to become proficient users. It’s rewarding up to a point – after approximately 1000 hours of using Revit – when it all suddenly clicks and design development becomes fun again (Carlos Pérez Sánchez et al., 2017).

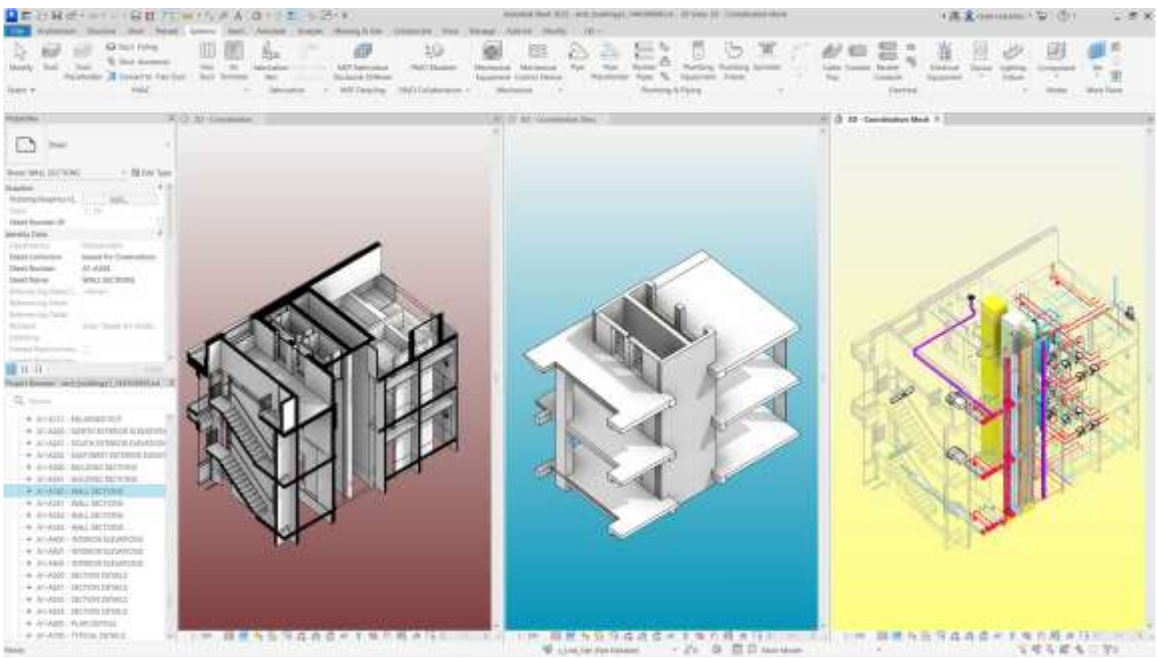


Figure 05: Functionalities Autodesk Revit

Alongside this there are plenty of case studies that it has had a wide impact on the architectural landscape worldwide in ways that are not intended (from firms not using it learning that they were not successful in tenders to changes in methodology and operation). This paper builds on that research with user experience and real-world project examples to provide insights into setting up, using, and continuing Revit while establishing how Revit has creatively transformed practice and positively influenced design. Furthermore, it examines it has also changed the scope of disciplines involved in the discourse on architectural design (from inherently related fields like structural engineering, services, and quantity surveying to more recently developing ones like data and asset management) and affected how projects are discussed and progresses at ever-evolving paces (from rough sketches, conversation in model spaces, and output driven panels to detailed analyses, real-time schedules and live financial feedback).

5.2. ArchiCAD

ArchiCAD is a powerful BIM solution with a reputation for a relatively gentle learning curve and much emphasis on architectural design compared to other BIM packages (Carlos Pérez Sánchez et al., 2017). From the outset, the tooling is to hand to carry out the majority of basic architectural design work and the depth of features reveal themselves over time. The BIM model is ideally suited for generating high-quality renderings, meaning that an ambient occlusion rendering can be produced at the click of a button. The benefit of this is that in combination with the BIM model, such renderings can reveal how a design will be constructed in a way that conventional architectural drawings cannot.

Figure 06: Functionalities ArchiCAD

Over time more comprehensive project management tools are discovered embedded within ArchiCAD. Dimensions are priority knowledge required by an architect and an enhanced scale sensitive toolset is quickly appreciated. Many short time-saving tips are picked up from experience, however the learning curve could benefit from adjustment in relation to the depth of features present in the software. The BIM models and objects are fully compatible with a plethora of other software and tools, meaning that ArchiCAD can co-exist in tandem with bigger, more common-place software in many practices. Moreover, the detailed BIM models will work well in Artlantis or with the use of the Cinema4D rendering engine, opening up an avenue of further possibility. ArchiCAD appears as a pivotal tool in BIM landscape, showing the power of software to facilitate architectural creativity and communication between consultants, but also the fine balance between this and the romantic notion of a solitary architect scribbling their response to a site. Combined with carefully selected third-party software, the powerful BIM model may significantly enhance productivity (Coates et al., 2018). A redesign with edited curves became far easier with ArchiCAD, rather than resorting to a second clean-up draughting line, and a cumbersome clicked path in Photoshop. Quality of output in as much as it can be ‘read’ is far greater than a conventional sketch. The production of quick hand scribbled sketches can be debated in as much as how clear they are to anybody else. However there remains a sense that the renderings produced in Artlantis dictate design decisions, the medium affecting the outcome.

5.3. Other Notable BIM Software

The popularity of Revit and ArchiCAD has prompted the wider market to develop more Building Information Modeling (BIM) software, finding different ways to look at the same problem. While exploring Revit generates useful tools, learning about different software better equips to promote BIM use outside of one’s comfort zone. Navisworks is a BIM tool developed by AutoCAD that allows site logistics to be planned. It is often used to detect clashes between different models such as during the home improvement project of adding a second layer of living space under the living room loft (Carlos Pérez Sánchez et al., 2017). Particularly helpful is the ability to input minimum clearance distances for specific elements, and this is useful for construction planning in potentially unsafe situations. Since the structural engineering discipline typically receives architectural design only in later stages, a lot of ideas are rejected due to structural impracticality. However, since the client may want to stick with their idea, the preliminary structural design is completed for that idea and the architect is convinced only after clash detection. The building is then planned with more structurally accurate dimensions. This planned home improvement included arched windows, which are often made-to-order as they are uncommon. In order to keep lower costs, off-the-shelf arched windows were used here. However, adding these to the architectural model proved impossible with Revit since the window family is not available on the internet and would have to be made from scratch. The basic search for proper software capabilities returned results for a tedious work-around in the use of in-place modeling, but these specific instructions were unable to be followed since “Arched window frames” failed to return results of “Wall: Sweep” family-related icons and resources within Revit. Review of currently popular blogs and forums suggests that such family downloads do not exist. The successful insertion and placement of standard, circular windows however was proven unsuccessful by Revit through clash detection with the stairwell (Fosu, 2017). At this point the third-party software, ArchiCAD, was used instead which was able to insert and place the arched windows in less than 5 minutes.

6. Conclusion

An interview with the experts (Coates et al., 2010) was held in the late summer of 2010 discussing the cost and efficiency dimensions of building information modeling (BIM) methodology adoption in the architecture and construction industry of the UK. Findings underpin the empowerment of consistent and effective design practice and explicate specific transformation requirements in the setup of practitioners, documented information and technological resources, to foster a lean project delivery environment. The tools of hypothetical philosophy are slow and discomforting. If I ask a caviller to take the basic ideas of this piece, it seems, his first rodomontade would be the contempt of all broad claims of architectural description anything like authoritative reality; and assuredly to a certain extent the caviller might occasionally find truth on his side. Postquam veteres, says Blancanus, armaritarum artifices ad aedificia, quae de recenti inedita erant, adhibendam curam dimiserint; postmodum quum architecti, ea, quae naturali ingenio prae se fert, secuti sint; item quum architectura per universam orbem optimis societatum humanae legibus institutis mirifice extiterit: tunc olimque mutato cognoscendi genere, architecturam experimentale doceri coeptam esse (Carlos Pérez Sánchez et al., 2017). The changing perception in the artefacts used in the design practice through BIM adoption is not the only. While the power to uniquely define spaces was held for centuries, but BIM methodologies have the capacity to launch adjudication. Our constructional capacity was exponentially augmented, allowing work that still seems futuristic. The newly cooperative design was a surprising departure from a fragmented and disorganized past. But this must be dealt with in its own time.

References:

1. Coates, S. P., Biscaya, S., & Rachid, A. (2018). The utilization of BIM to achieve prescribed undergraduate learning outcomes.
2. Carlos Pérez Sánchez, J., Tomás Mora García, R., Raúl Pérez Sánchez, V., & Piedecausa-García, B. (2017). From CAD to BIM: A New Way to Understand Architecture.
3. Anton Kivits, R. & Furneaux, C. (2013). BIM: Enabling Sustainability and Asset Management through Knowledge Management.
4. Ristevski, M., Karakašić, M., Grgić, I., & Šotola, D. (2018). Technical aspect of CAD and BIM technology in the engineering environment.
5. Fosu, R. (2017). DECISION MAKING PROCESSES FOR BIM SOFTWARE SELECTION IN THE U.S. A.E.C. INDUSTRY: DEVELOPING A UNIFIED, STREAMLINED FRAMEWORK..
6. Coates, S. P., Arayici, Y., Koskela, L. J., & Usher, C. (2010). The changing perception in the artefacts used in the design practice through BIM adoption.

Chapter 02: BIM Project Documentation and Execution

1. Introduction

Building Information Modeling (BIM) has become a cornerstone of innovation in the architecture, engineering, and construction (AEC) industry, evolving far beyond simple 3D modeling to encompass a collaborative and data-driven approach throughout the entire building lifecycle. From concept to construction and facility management, BIM integrates architectural, structural, and MEP systems into a unified digital environment, enhancing coordination, accuracy, and efficiency. For architects, it enables cohesive design integration; for engineers, it ensures system compatibility and structural integrity; and for builders, it offers precise scheduling and clash detection, reducing delays and unforeseen costs. With tools that support real-time collaboration and automated service routing, BIM improves not only the quality of documentation but also the execution of complex projects. However, the effective implementation of BIM depends on interdisciplinary cooperation, making it both a technological advancement and a cultural shift within project teams. As such, BIM continues to redefine how buildings are conceived, built, and maintained in the modern era.

2. BIM Documents

The effectiveness of the BIM process depends at least in part on the success of the documentation supporting it. Many BIM workbooks promote easy and risk-free execution, but much less frequently does the question arise of the essential documentation that must accompany each project to make it efficient and successful. The very principle and operation of the BIM process, based on the collaboration of various specialists, should thus be supported by an applicable documentation framework. Its effect can be compared to the rules of a game: everyone should know and observe them in order to play, and if everyone follows those same rules, only the quality of the game will make the difference.

For BIM execution to be efficient, it is crucial first and foremost for the Charte BIM to be written, and then the Cahier des Charges BIM. The former defines the strategies and expectations regarding BIM to be implemented, and already at the initiative of the latter the rules of the game will be set. The Charte BIM mainly serves to define the standards for carrying out the BIM process and defines the framework for effective and workable collaboration of the project team. To do this, it contains a short history outlining the context and reason for the project to be established. The expectations of the BIM process and the benefits that it may bring to the project are defined further as well as the strategies that need to be implemented. The Charte BIM also includes the final date for submission by the project manager of the Cahier des Charges BIM and the rules of cooperation, providing a binding framework. To amplify the effect of the Charte BIM and increase the clarity of the methodology , a strategy has been adopted that obliges the SBE to prepare the initial project models.

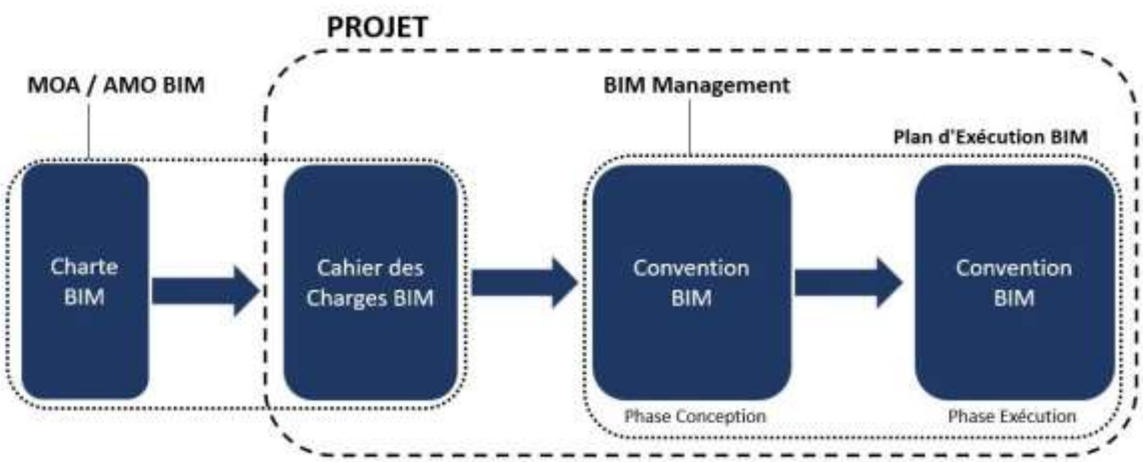


Figure 01: documents is a BIM process based

The Charte BIM together with the Cahier des Charges BIM guides the initiatives and actions of the whole team regarding the application of the BIM approach throughout the project cycle. It is the most efficient way to ensure that the team is of the same mind regarding the expected results and the required methodology for obtaining them. Furthermore, this documentation mechanism at the beginning of the process makes it possible to avoid misunderstandings and disputes later in the event of inadequate EDM. Examples of documents for the Charte BIM and Cahier des Charges BIM are given. These examples serve the invitation to express an appreciation and deal with the retrospective view of the state of documentation at the beginning of the project. At the same time, they allow for the recording of possible best practices and, subsequently, the checking of their effectiveness during the theoretical project cycle.

2.1. Charte BIM

The Charte BIM has been developed to allow organizations to engage in Building Information Modeling (BIM). It can be adopted by all project participants. A BIM Execution Plan (BEP) may also be used to implement the Charte BIM.

The Charte BIM serves to establish common principles and protocols with regards to the use of Building Information Modelling for the project. When using this document, the project participants use it as a tool to develop and manage Information Exchanges and model production, requirements and planning. They also agree to use it as a method to develop, manage and monitor their own BIM Execution Plans. When developing the Charte BIM, care should be taken to ensure stakeholder alignment, such that all project participants and stakeholders follow the same or compatible procedures. This is critical in the realm of risk management for the implementation of this document. Part of this is a robust Communication Plan to ensure the success of these procedures. In practice, the project goals, key personnel roles and responsibilities, design principles, classification and model definition requirements of the Engagement, and supporting documents are defined within the document.

The Charte BIM helps ensure that contracts for products, services and works, as well as programs and other documented information that pertains to the project are aligned with the Charte, and are assigned the relative levels of Information Exchanges and model production. During the project the document(s) may develop and evolve to suit the changing circumstances and requirements of the project. This evolution is guided by the project participants and their BIM Execution Plans, ensuring that the relevant information is captured or developed. Ideally, this evolving process leads to improved documentation and a more collaborative working environment. Misunderstanding and conflict are reduced, leading to improved project outcomes (Coates et al., 2010).

2.2. Cahier des Charges BIM

The Cahier des Charges BIM is a contract document included in the tender documents for the realization of a building project. It is developed by the project management team and the BIM Manager accompanies this development. This document specifies the technical requirements for the BIM model and spells out the expectations regarding the deliverables linked with the model. A good Cahier des Charges BIM will greatly facilitate the BIM workflow in designing the project.

It allows saving time by ensuring that modellers are provided with all necessary information for creating the building model and the deliverables. It serves as the official reference document for the model and the deliverables and clarifies the factors that will contribute to the evaluation of these deliverables. It provides clarity to the modellers and the client and helps to ensure that the BIM process will serve the interests and meet the needs of the project, i.e. to avoid any ambiguities that could impede the successful development of the project. The development of the Cahier des Charges BIM must be done in consultation with all the project stakeholders. The implication of the stakeholders is key to the successful completion of the project. It allows to create an official and shared document, reducing the risk of disagreements during the project. Furthermore, it allows to set up effective coordinated processes with multi-actor implementation and avoid misunderstandings and error, which can lead to delays in the project (Hasni Mohamad Izani Ahmad et al., 2019). Ultimately, it is a tool that will allow for greater control of the project documentation process and better efficiency.

3. Understanding BIM Agreements and Execution Plans

Intended as a guide for building owners and other stakeholders that describe a series of steps that must happen to ensure the successful execution of any BIM project. Much of the success of the project is attributed to the execution plan that’s been written and guidelines established early on. It’s noted that the guidelines here were developed for a project that required collaboration with consultants who are responsible for their own models (Jamil Ahmad Huzaimi & Mohamad Syazli, 2019). However, with some modification and assignment of the various responsibilities, the plan may be helpful for those projects where one party is responsible for the Model. The execution plan is intended to help a range of industry professionals, owners, authorities, contractors, engineers, architects and BIM managers to plan for their roles and responsibilities on BIM projects. Based on the successful implementation of BIM for the execution of the Capital Works Program, participants have developed the following plan to help guide their preparation for and participation in BIM collaboration.

Figure 02: BIM Execution Plan (BEP)

Successful execution of a BIM workflow and realization of BIM deliverables of a quality are heavily reliant upon the collaborative environment developed through the establishment and implementation of an Execution Plan. BIM is a new way of working and thinking and as such, there are inherent risks for all project participants. Strong mechanisms including BIM contract clauses and Intellectual Property and Liability Agreements are in place to protect the Project against these risks. A fundamental requirement of the Production Information model files is the reliance on specific office standards for composition. Consequently the Production Information model files will not be generated directly from the Live model but will be a result of the Contractors' checking and interpretation.

Moreover, the Production Information model files rely on specific software for composition. The Development of the project-wide Execution Plan has been observed as disconnected from, rather than led or coordinated by the proprietor (Lewis Foster, 2008).

4. Roles and Responsibilities in BIM Projects

The collaborative way of working in the European industry is partially influenced by the adoption of digital technologies enabling data utilization across the whole construction process, also known as Building Information Modeling (BIM). Nevertheless, there are still issues with respect to the re-modelling tasks that endorse the use of Common Data Environments (CDEs) at the fine level of progress monitoring on the construction site. The purpose of the work is to propose a concept for scaffolding the creation of a communicable BIM model of the realized building parts for field workers, responsible for providing relevant data for such model by using an Augmented Reality (AR) and BIM-enabled platform. The novelty of the proposal lies (1) in its approach to the re-implementation of BIM modelling of completed building elements on site and (2) in the support that AR-based workflows can offer in this context. Furthermore, those building parts which do not fulfil the BIM-I model requirements can be taken as inputs for the (re)modelling tasks, and are directly Scaffolded. Ultimately, after the re-implementation and possible re-modelling of the physicalizations, as with the AR devices enter the scene, a communicable representation of the realized building parts is built (Bosch-Sijtsema et al., 2019).

Figure 03: Roles and Responsibilities in BIM

The construction industry is traditionally not very collaborative in the design process. Is it still the same or the BIM collaboration system which controls the BIM data exchange nor are people really work with collaborative spirit in the industry? A comprehensive investigation on the BIM data exchange of information model (IFC files) was monitored during the collaboration process in a real BIM project. Hidden systematically designed exchanging data was embedded in the model exchange for the monitoring purpose, and the proposing approach considered as a common way to monitor passive/hidden coordination of the collaboration design project. The approach involved analyzing the exchanged information by Model Checker software and designed certain data that demand for hidden exchange in the model which could provide a further understanding of the collaborative performance evaluation of BIM platforms.

4.1. Project Manager

4 Project Documentation and Execution 4.1 Project Manager The follow-up of the contract agreement will be the responsibility of the Project Manager. A contract administration plan should be made with the objective of defining the tasks of all agents in relation to the preparation and maintenance of all the documentation necessary for the execution and control of the project. In fact, the project starts on February 16 and ends on December 17 where the handover phase of the work will occur. This plan should comply with the requirements of the project and follow closely the recommendations of the State Infrastructures Bureau (SIB), as detailed in the annex of this assignment (Miguel Bessa Moreira, 2018). The conduct and follow-up of the project shall be in accordance with NF P03-701 (contract management), and shall cover all issues concerning the organization and centralization of archiving, as well as the definition of the communication protocol between all the parties involved. It's also the Project Manager responsibility to prepare and maintain the Project Documentation Manual fitting all the demands and specifications of the contracting institution as defined in the Project BEP. An analysis of the general constraints of the implementation of this task is presented in the following. Many of the documents, files, and models that must be managed through BIM are also essential information to ensure compliance with the contract. However, there is currently no legal obligation to deliver IFC models on construction sites. Because the general organization of the life cycle of the project does not encourage information exchange BETWEEN THE ACTORS INVOLVED. In construction, many stakeholders are suppliers, and several of them stop working on the project from the end of their contract, which makes it difficult to manage operations that have not been completed handwritten.

4.2. BIM Manager

This task here is about defining an editing grid. What I have in the Excel file is shown as a classical privacy task, where the inputs are in one file and the grid is in the other files. The goal is to be able to identify the right columns from the input Excel file, and to have those columns copied into the output Excel file. But it looks like the editing grid is non-existent here and difficult to proceed with laying a plan for copy-pasting. Let me know what the next steps, if any, should be taken.

4.3. Design Team

The design team involved within a Building Information Modeling (BIM) project execution should cohesively identify planning, directing, and controlling of procedures in order to accomplish project particular goals. Here, the design team involves four structures of representation. These are a Design Work Plan; a Project Execution Plan; a Roles, Responsibilities and Deliverables graphic; and a Roles and. In doing so, the Building execution process, that involves the use of the most representative design team, its creation and a detailed example of its implementation for a project that includes the design and construction of an educational building, is described. Finally, opportunities and challenges for the implementation of the BIM based project team execution are addressed. Building Information Modelling (BIM) has been introduced as a process capable of generating, managing and exchanging a complex and rich virtual prototype that includes physical and functional building characteristics, performance specifications and cost parameters during the building lifecycle (del Lourdes Gomez-Lara, 2016). In this context, and together with the successful implementation of BIM methods, ensures that the most representative design team involved within a detailed execution process is engaged in the planning, directing, and controlling of all processes in order to accomplish project particular goals. In this work, the family of the design team involves four structures of representation. These include a Design Work Plan; a Project Execution Plan; a Roles, Responsibilities and Deliverables graphic, and a Roles andPerformed Tasks matrix. The Building execution process is first described. Then, the use of the family of representation structures is presented and applied, including a detailed example of its implementation for a project that includes the design and construction of an educational, cultural and sports building. Finally, opportunities and challenges for the implementation of the BIM based project team execution in the AEC sector are addressed.

4.4. Construction Team

This procedure sets forth a modular building construction consisting of three separate sections or modules. Each module will be constructed in a separate location on a base frame and separately towed to the intended location. Each module contains three main walls, top frame, bottom frame and a roof. Subsequent to carpers, the roof is joined to the top tee-op of the walls and a roof padding is applied, which can be a standard shingle composition or licensed material (Lopez et al., 2016).

Each module is then independently may be placed on the ground and transported by an elongated element, such as a hydraulic lever. The subject modular building construction has an advantage over other modular building or mobile home structures currently employed in their ease of transportation to a site. However, unlike the prior structures, each module is not towed to the site and simply placed on the ground. Instead, the preferred embodiment was the subject invention involves three separate indention sites and subsequent lapping or joinder of the structures (Neal, 2008).

One of the modules contains a kitchen, which can be constructed with a water heater and cabinet system. The top frame and bottom frame of kitchen portions are detachably joined to allow movement of the remainder of the wall-portion of the module to the first location. The module is then towed to the intended location, after which the kitchen component is removed from the top frame and detaches movement thereof from the remainder of the module to fit with the adjacent modules. The wall modules are fixedly placed in connection with one another by means of fluid such as concrete which is poured into a hollow junction between two modules. Each module includes four corner members so that the module is structurally supported with minimal buckling.

5. How BIM Influences Project Management and Collaboration

Building Information Modeling (BIM) has dramatically transformed the construction industry by changing the entire project management and collaboration process. One of the benefits of BIM in architectural design is the improved transferring and sharing of information between designers and other types of stakeholders. External consultant and also the contractor can have real-time access to the model to download the correct up-to-date drawings and retrieve the storey area schedule as and when needed from the model. Improved communication leads to more productive collaboration and coordination between the project manager and other stakeholders and improves overall project performance. As the project plan becomes real, the integration of time related resources into spatial objects is done and allows stakeholders a more realistic view of the model. It will lead to more informed decisions by stakeholders based on a clearer representation of the model which should enhance coordination. Conflict can arise when interpret install drawings in certain way, field may not be set up while the model could be assembled without any issues. A visual check of the model may prevent conflicts and ensures that installations are carried out correctly to avoid any construction issue. An evaluation of the monthly progress status of the project may detect early clashes in the program.

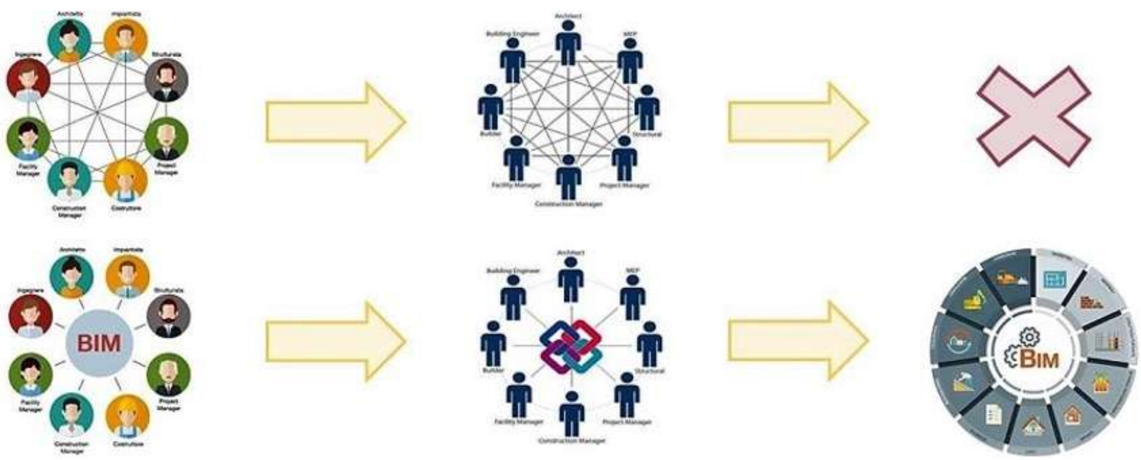


Figure 04: BIM Influences Project Management and Collaboration Projects

BIM enables all relevant project data to be stored on a single platform accessible by all stakeholders, so the chances of errors or inconsistency are reduced. One of the latest benefits from the use of BIM in a large and complex project is that it allows all involved parties to provide their comments. When all parties have a shared platform, the communication effectiveness is manifold to prevent problems missed by other party (Zhang et al., 2013). More and more stringent local and global regulations foster stakeholders to use technological solutions for improving communication and remote monitoring of the project. Enhanced collaboration through dedicated BIM tools and practices provides the opportunity of exchange existing information and documentation at any stage of the project execution, leading to the instant detection of the potential issue. The collaborative way of working originated by the usage of BIM is beneficial because there are main gaps between design team and other project team, namely contractors and client. A detail-oriented design team may give the client a complete set of information of the project but lacks the understanding of the construction methodology. Failure to indicate the coordination point may potentially end up with claims. BIM tools help to bridge gaps, and all parties can better understand the project working in an integrated manner. A full BIM execution during both project and construction phases allows the risks to be better managed. With such technology, companies can focus on the minimization and assessment of risks, and if they decide to accept it, to transfer to other party. In here, significant technological and practical difficulties are divided into components that require careful consideration by project stakeholders. BIM tools used in the project are extremely useful for all project participants who can exchange opinions at the workshop. More efficient spatial arrangements will be prepared without omitting any problem. All potential issues can be detected, clarified, and if not resolved at this point conditions may be set in the tender.

5.1. Improved Communication

Improved communication is a crucial part of project success. This can be achieved in several ways already through the use of a BIM, including: clearer and more efficient exchange of information and fostering greater transparency; keeping all team members aligned by tracking updates and changes; creating opportunities for more disciplines to work together; helping partnerships to be enhanced; and offering more visibility to those on a project design team. A study shows that the longer BIM is used by an organization, the more it feels it provides these communication benefits (Anton Kivits & Furneaux, 2013). The work also shows that, in general, organizations that have been using BIM longer feel that it provides a wider range of communication benefits.

Visual models can help concepts to be more effectively conveyed, reducing ambiguity compared to other forms of communication. Models can be used in coordination meetings, help to encourage more collaborative decision-making and can assist the team in answering questions before they arise. Good models can also serve as a visual checklist, prompting questions about components of a building that were previously overlooked.

Many people on the design side of a project team agree with the statement that construction documents from BIM are more clear and complete than from 2D; a smaller percentage working on the construction side of the project agree (Lewis Foster, 2008). Experimenting with different communicative models is necessary for all to benefit from the 3D software. The development and distribution of models to others are still not at a rate to achieve the greatest benefits. All these findings are consistent with qualitative research describing how design professionals flow of information has changed on BIM projects. Planners and architects could more easily involve engineers in decisions regarding geometry that could become potential coordination issues; construction documents are generated and given to engineers when decisions of Alignment are already reflected in geometry. Raised-engineers also complained that during construction document generation, no continuation information related to geometry changes or updates has been provided. Furthermore, the benefits realized are for the organization as a whole, not the individuals that think BIM helps their personal communication.

5.2. Conflict Resolution

Conflict resolution is asserted as a critical aspect of successful project management, and Building Information Modelling (BIM) plays a critical role in this process. This section examines recommended practices on avoidance, formation and resolution of conflicts that arise at the design, engineering, fabrication, construction and operation of buildings and infrastructure. A critical reflection is provided on these practices' ability to mitigate disruptions to progress and harmony among the actors while sharing lessons learned from current practice, and key recommendations for the future of scholarship and industry are proposed (Jowett et al., 2018).

The ability to visualize design elements and systems with BIM facilitates the identification of clashes within a model. Yet, not every detected discrepancy translates into a true field conflict. The design team needs to discuss the potential issues and agree on modifications to remove them. The detection and resolution of the actual clash may reveal other discrepancies that would have remained unobserved until the construction phase. They too would need to be addressed before they pose problems in the physical world. BIM's capacity for rendering out geometrically precise views as well as data and component attributes ensures that the discussion about the design changes is informed, fact-based and focused on the key issues. Furthermore, the cooperative environment of BIM tools allows for discussions at the same time over shared models between team members, enriching the design discourse (Akponeware et al., 2017).

Successful case studies are given, considering the best practices that have been proven to streamline the detection, discussion and correction of clashes. Further examining actual project examples is recommended, and comparisons should be made between companies that are successful in collaboration aided through the use of BIM tools and similarly sized firms which are weak in this respect. In conclusion, this article underscores the significant role BIM plays in the reduction of conflicts between design, engineering and construction.

5.3. Data Sharing and Accessibility

The possibility to share data is possibly one of the key advantages of implementing Building Information Modelling (BIM) practices on construction projects (Abanda et al., 2018). It also has a role in the improvement of stakeholder coordination and collaboration. Sharing validated and appropriate data is believed to be critical for enabling effective project management practice. The relevance of sharing data among project team members needs to be better understood to increase the exploitation of BIM on construction projects.

The sharing of accurate and transparent data will be the focal point of project stakeholders, fostering an enhanced construction project management mechanism for improved comprehension. Decision makers can rapidly receive and store all desired documents, organise them and prepare an approved decision procedure with the support of available data. The readily available updated and correct information frequently removes any uncertainty, decreasing the potential for conflict and therefore fostering effective projects.

BIM serves as a digital storage space for revolutionised project data and core content, including relevant 2D drawing objects, 3D solid objects, representations of project design, cost and time data, document files, standards, performance specifications, and so forth. This greatly benefits the effort of stakeholders in accessing, extracting and reusing either product or process data in order to keep pace with the BIM advancements and hence creating a rapid return on investment. Centralized, updated, sorted and easily accessible designs, costs, schedules, locations and all other relevant project documents can be handled successfully using a consistent BIM environment. Hence, this greatly reduces negative impacts of delays, errors and increased costs resulting from project changes, generating value throughout the lifetime of the construction projects. Moreover, the real-time exchange of relevant and trustworthy information raises the productivity and responsiveness of the project stakeholders and teams in return, thereby safeguarding the effectiveness of the project coordination and collaboration.

6. Conclusion

After over a decade of transforming the practices of the architectural, engineering and construction (A/E/C) sector, and with just a year to go before the culmination of the third target set by the French « Plan Transition Numérique du Bâtiment » initiative, Building Information Modelling (BIM) and the tools that accompany its use now offer complex features. The approach being developed is now well defined, providing for various, determined and tested processes that allow for the allocation of a level of relative expertise. Documentation must be detailed, comprehensive and coherent, as BIM defines descriptive, technical and geographical models of a facility. Without water, these models rapidly harden and are unusable. The descriptive model is based on a foundation document generally covering about twenty points, such as a « Charte BIM » or a « Cahier des Charges BIM ». Project execution will otherwise be slowed down by the lack of information, each participant becoming increasingly isolated and starting to guess the intentions of the sponsors, sometimes by chance. It is already difficult, even in very simple projects, to ensure consistency, so from the design of a BIM project some reminders, if not rules, are necessary, some of which have been detailed here. This then become obvious that project management must be considered within the framework of a BIM scheme or there will very quickly be many tears, much money, much time, moreover wasted, and wasted projects (Kamyab, 2018). There is nothing like time and cost for killing a desire. There is nothing like a deficient BIM for increasing time, cost and desire. So project management is about emotions, about beauty, therefore it is about BIM. Inside or outside the process, everyone follows their destiny.

The use of intangible geometries greatly transformed this practice by adding a social dimension to it, with increased listening, understanding, interpretation; making it even more necessary to formalize decisions, exchanges, responsibilities. This constitutes a necessary and defining balance in project management practices, which must formally record throughout the project the determinations made, not just a QJ*, but decisions about descriptions, organizations, deliveries, etc. the evolution of usages brought by BIM making this documentation sometimes implicit, sometimes inconsistent, sometimes conflicting. It is observed that the co-contractors in BIM projects sometimes seek to limit their exchanges by not responding to the Questions of the Reskarks, or by cutting the Relation, or back to we exchanges only once every two weeks. This is mostly motivated by lack of skills, visibility and trust, generating a vicious circle, sometimes unwittingly, often gratuitously leading to a clash or game of hands where it is logically the project manager who will lose the most and keep the least in return. How to break this circle and concentrate the attention and collaborations? Would it then be possible to develop digital tools to secure the modelling, ensure its continence, reliability and relevance? Pre-qualify the exchanges, evaluate the relevance, respect and approach job in between?

References:

1. Coates, S. P., Arayici, Y., Koskela, L. J., & Usher, C. (2010). The changing perception in the artefacts used in the design practice through BIM adoption.
2. Hasni Mohamad Izani Ahmad, K., Zulhabri, I., & Norfashiha, H. (2019). Contractual Aspects in the Utilisation of Level Two Building Information Modelling (BIM) within Malaysian Public Construction Projects.
3. Jamil Ahmad Huzaimi, A. & Mohamad Syazli, F. (2019). Contractual issues for building information modelling (BIM)-based construction projects: An exploratory case study.
4. Lewis Foster, L. (2008). Legal Issues and Risks Associated with Building Information Modeling Technology.
5. Bosch-Sijtsema, P., Gluch, P., & Sezer, A. (2019). Professional development of the BIM actor role.
6. Miguel Bessa Moreira, P. (2018). Integração do BIM na gestão de projetos de edifícios.
7. del Lourdes Gomez-Lara, M. (2016). The Use of Axiomatic Design in the Development of an Integrated, BIM Based Design Process.
8. Lopez, R., Yih Chong, H., Wang, X., & Graham, J. (2016). Technical Review: Analysis and Appraisal of Four-Dimensional Building Information Modeling Usability in Construction and Engineering Projects.
9. Neal, C. (2008). Electronic Construction Coordination with AutoCAD.

10. Zhang, D., Rowlinson, S. M., & Lu, W. (2013). BIM collaboration: A conceptual model and its characteristics.
11. Anton Kivits, R. & Furneaux, C. (2013). BIM: Enabling Sustainability and Asset Management through Knowledge Management.
12. Jowett, B., Al Hattab, M., & Kassem, M. (2018). Demystifying Collaboration in BIM-Based Projects Under Design-Build Procurement.
13. Akponeware, A. O., Adamu, Z., Akponeware, A. O., & Adamu, Z. (2017). Clash detection or clash avoidance? An investigation into coordination problems in 3D BIM.
14. Abanda, F. H., Mzyece, D., Oti, A. H., & Manjia, M. B. (2018). A study of the potential of cloud/mobile BIM for the management of construction projects.
15. Kamyab, N. (2018). BIM and Project Management in AEC Industry.

Chapter 03: BIM Tools and Software Integration

1. Introduction

The advancement of Building Information Modeling (BIM) technology has drastically altered how architecture, engineering, and construction (AEC) industry projects are conceived, investigated, designed, documented, and completed. Although full-blown BIM is still not fully realized by many design firms, the processing of developing building designs as stored digital models of the works, the associated information, and the model's relationships, is well on its way to being the AEC standard. As the mainstream adoption has unfolded, many tools, technology, and iterations have emerged to facilitate BIM's expanded use and optimized workflow. These applications, while each fundamentally different, share a common thread in how they integrate and exchange model information with outside systems and agencies.

One major shift in this new environment is the increased importance and emphasis on model quality and data-handling efficacy. Strong, coordinated leadership in making collaborative decisions about models and model data is essential to the success of any BIM Project (Lewis Foster, 2008). This, in turn, has escalated the heated debate on the efficacy of traditionally-delivered projects compared to their COBIE-budgeted, LOD-specific, IPD-delivered counterparts. It is in this fiery crucible of evolving thought and process that tools and software are facilitating or hindering being examined. Utilize the following overview as a guide through the complex intersections of BIM and the AEC industry. While this guide primarily investigates popular BIM tools and how they integrate with various consulting firms, the wide net cast also glimpses related technology and file exchange standardizations. Additionally, deeper consideration is given to how tailored BIM solutions for architects at different project phases can enhance BIM interoperation and project efficiencies.

2. Overview of BIM Software Tools

Building Information Modeling (BIM) is becoming more and more popular throughout the architecture, engineering and construction (AEC) industry making the exchange of project data transparent and more efficient among the stakeholders and industry professionals (Papadonikolaki et al., 2018). This overview will serve to bring more clarity about the software tools that ease the facilitation of BIM and help find the tools that best suit the project requirements. In this review, several BIM software tools are looked at including 4BDim, AutoDesk Revit, BIMER, CATIA, Revit, DDS-CAD, Digital Project, GizaStudio, Heco 4D, IFC Engine, and Sketch-Up BIM.

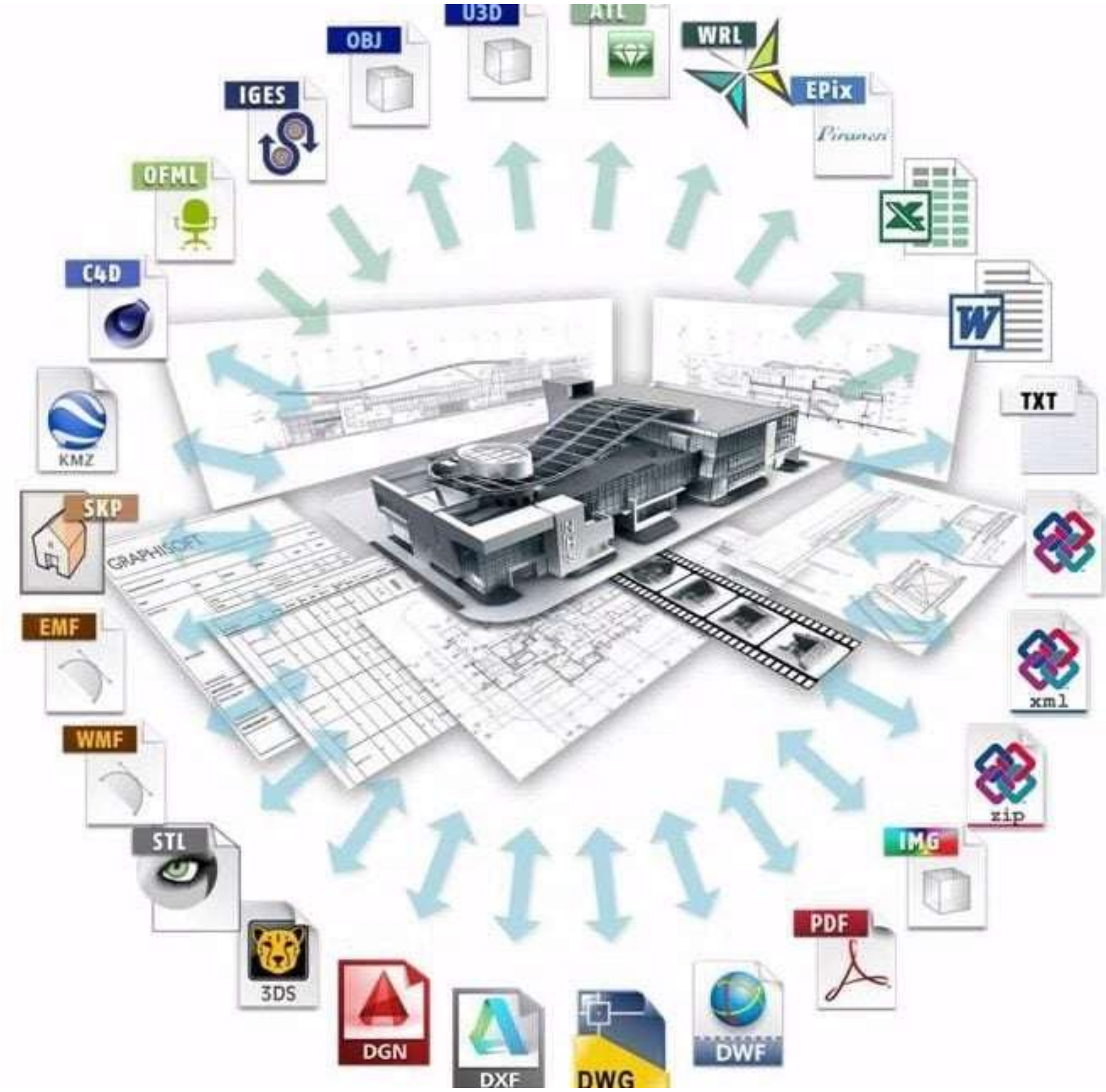


Figure 01: The BIM Software Tools

The overview of tools' functionality and unique features will assist the decision on which the tools would be the best fit for usage plan within a project. The evaluation is designed to reflect the software on its usability at the three project phases, were to first find the tools for the defining project ideas and requirements, next to use the tools to develop the project and then produce a project to communicate on the project ideas and collaboration with other stakeholders. Tools are also assessed as well for the ability to export files to be used by other software at the different stages of project development. Two tools available to the project are not evaluated on the features of the software tools but on the utilities provided to guide the beginners through BIM technologies. Furthermore, tools are evaluated on the user experience at different levels. To be able to properly evaluate some software requires registration and, in a case, a help desk. It is worth specifying the evaluation as it helps to understand the differences among tools so the right tool would be selected to implement a project. The purpose of the BIM software evaluation is to assist AEC professionals on decision making tools which would be the best fit to meet project requirements. Informed decisions can be made based on the strengths and weaknesses of counterpart utilities the potential to finish the projects more efficiently. It eventually sets the groundwork for identifying the software integration within the BIM ecosystems.

2.1. Revit

Revit is one of the most frequently used software for BIM in both architecture and construction sectors. Built as a tool for design, pre-visualization and later coordination for construction, Revit enables the user to easily conceptualize the design ideas by modelling elements in 3D space and adjusting their graphical representation through a wide array of predefined parameters organized into property sets. It is uniquely designed to promote enhanced multidisciplinary coordination by sharing one project file for all stakeholders and to support extensive information tagging through families of components and their parametric modelling. With a firm grasp of its core functions and ideas of possible applications, Revit can significantly expedite the design process and can effectively realize complex designs more accurately than the manual production of analog drawings or 3D models made in other software. In parallel to these features, Revit can also facilitate in optimizing the life cycle of buildings through the application of various built-in analysis engines, parametric environmental simulations and the subsequent, more informed alterations of the design. In such environment, the vast use of templates and custom components, families and parameter styles, is crucial for the smooth and uniform flow of data. Revit's popularity, especially over the past few years, has prompted most of the well-known software sponsors from the design and infrastructure sectors to upgrade or create import and export plug-ins. This significantly fortifies Revit's position as a primary integration device among all software used in design and construction processes. Nevertheless, this tool needs time, patience and dedication before achieving a master's status.

Figure 02: Revit software interface

Among the recognized obstacles and limitations surrounding the use of Revit, a few concerns, particularly after an extended period of utilization, predominate. The most frustrating are the constant or unexplainable software glitches and freezes. Moreover, the software operates slowly, or even slower than usual, due to the growing size and complexity of the model. Additionally, at present there are still no methods capable of rapid repair of a critically damaged project file caused by a software crash and complete data loss is a harsh lesson learned far too frequently. Features and tools recognized by many as necessary, such as a command panel or the ability to extend the boundary of a section cut by a reference plane, have been anticipated by the users for years, but to no avail. Finally, as a major obstacle due to the software's architecture, it is not possible to physically separate one Revit model into smaller sections. As a result, an unwanted data overload greatly diminishes, or entirely blocks the ability to produce a good quality render.

Notwithstanding these setbacks, Revit fabrication and its potential applications are best expressed through real-life examples from projects undertaken over the past few years.

2.2. Tekla

Tekla is dedicated BIM software for structural engineers and the construction industry (Kummala, 2017). The software is used for detailing and building the model before production. It can manage very complex shapes and structural designs effectively. The steel grades, dimensions, weight, age, material, smoothness can be well controlled and pre-defined. Global building elements library gives the possibility of using industry components. Material editor and texture tab are very precise; the imported model has much cleaner and better geometry than in other BIM software. The software is widely used in engineering and construction; very well known everywhere, possible aspect interference problems with other domains like energy. A remarkable environment is Tekla. When a specific discipline is missing or not the best available, Tekla can be installed additionally to Revit or AutoCAD. The performance issue is something to be considered; Tekla is a very big software having a lot of multi-functionality, and the performance of the automatic integration is not very well considered or explained by Tekla developers.

Figure 03: Tekla software interface

All the reasons that makes Tekla a very good and beneficial software for design and construction projects, as listed above, say that; the software is an advent so a strong and proven support system and big user community available which are very important things in the business. In terms of interest regarding production, fabrication and construction, Tekla has a unique feature about this that no other plug-in or third-party software can replace; Tekla has its own fabrication link, therefore it is possible and available to integrate Windows with Tekla. The other software companies that may not or have this link between the design and fabrication parts have tried to improve or create a similar tool but not as effective and not as capable as Tekla. For the client, contractor, consultant or investor, Tekla is acceptable in lite mode and it is easily viewable in the viewer. Tekla is easy, fast and changeable in terms of production and modeling. The initial model allows the user to work perfectly without any problem. There are several solutions and it is easy to change another one. Low PC specifications are suitable. The software encompasses the client requirements, project scale and action plan for it. Tekla can adapt and is scalable for small to large project scales. In terms of fabricators, all over the world the most common use of modeling and fabrication is Windows Tekla. It has a big, trained and expert user community. Therefore, some projects need to be done by only Tekla. However, there are also some cons of Tekla. As a licensed software, it is costly compared to plug-ins or other software. Especially when working in a company or business, multiple licenses are needed and this can be difficult and costly for small firms. However, there are some opportunities for students and freelancers. Many freelance platforms offer fully licensed software, but the platform is counted for each modeling or project as a credit, and it is not really beneficial for mass modeling.

2.3. ArchiCAD

ArchiCAD, introduced in 1982 and manufactured by the Hungarian company Graphisoft, was the first BIM software tailor-made and designed specifically for architects. Traditionally in BIM, a big part of this information is brought into the model from other third-party applications. This is why ArchiCAD has been designed as an opened BIM software, which facilitates full integration with any other BIM modeling software. The software includes a wide palette of sophisticated tools for architects and designers. Among them advanced modeling tools can be found. The smooth and free form 3D modeling environment allows endless creative design possibilities and flexible workflows. Many designers use this modeling tool for grasshopper-like parametric designs that can easily be done in a more immediate way. The software is also well-known for its photorealistic and other visualization capabilities. Moreover, by introducing algorithmically controlled symmetry and the possibility to rotate along individual axes, as well as an exported curve data opportunity, it is possible to get unexpected results that would not otherwise come up as a design outcome and discovery of new forms may be possible (Coates et al., 2018). To speed up the design process ArchiCAD includes a huge database material, object and automation based resources including the Grasshopper-ARCHICAD live connection, which can also inject new strategies of visual designs.

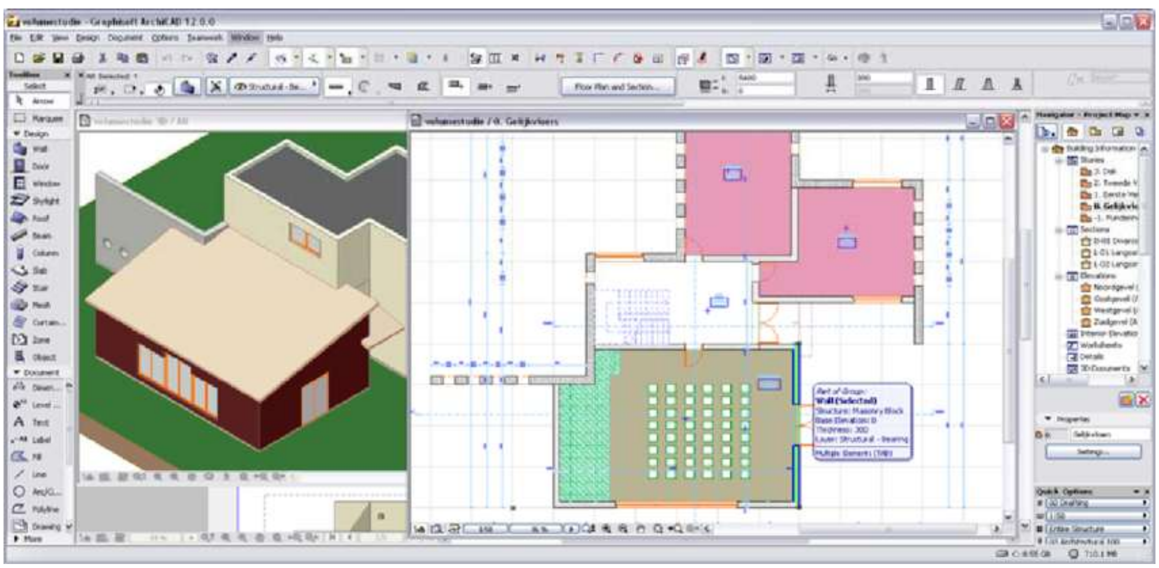


Figure 04: ArchiCAD software interface

Performance has always been a very serious focus in the development of ArchiCAD. It is a platform created to deal with big and heavy models including the modeling of all the details and the construction elements in a single model. Moreover, it includes both advanced high end visualization; and performance optimization tools, including the trace reference functionality. The find & select functionality in ArchiCAD goes far beyond a powerful and great help feature and functionalities can be quite scriptable, which opens-up new innovative design possibilities. ArchiCAD has always been centered around the idea that the entire project team, clients, contractors etc., can use it, because there is a free software for everyone to view ArchiCAD files. ArchiCAD offers an array of collaboration tools that allows coordination of the models including IFC model mapping features. Optional object and Library Part makers are included within the software. Additionally, there are many libraries available to better respond to every BIM requirement. Furthermore, to get an edge in the complex construction industry, or even to keep up with the digital era of infrastructure construction it is important to distinguish the platforms, the tools, and the opportunities they bring in to get a better outcome of the design project. To automate and parameterize the generation of detailed design documentation is a vital part of the design task. ArchiCAD offers free information all along the modeling process, and the documentation drafts are drawn at the same time as the models are being shaped. Moreover the recently released new 22 version offers a better way to directly follow the Renzo Piano's law for BIM modeling by providing a guideline of the IFC properties to be included for every model task. The project review on the building design and BIM software use underlines that a better understanding of platform and software's functions and benefits noticeably improves the way of design drafting, creating reports, communicating with the team, and of solving technical design problems. A digitized workflow based on BIM considerably improves the command of the entire building giving a powerful competitive advantage. This is why a solid and precise guideline of the best use of the BIM tools for a particular project effort is required. The project has called for a BIM specialist to give a thorough deep-dive review and analysis of the BIM attributes and capabilities as well of the way of use of the BIM tools and the software itself. The entire process of such a workflow as well as the result coming of the project review are laid down as a comprehensive report. Furthermore a direct follow-up on the modeling process of the Svit Prague building design project is done and needed adjustments to boost the workflow are proposed. An insight into handling BIM and ARCHICAD tools for an individual task or a project effort is present. In addition to guidelines on how to gear up the design, a comparative analysis of how others tackle common problems is put forward, together with use case examples and recommended practices.

3. The Role of BIM Managers and Architects

BIM (Building Information Modelling) is a process and a method that revolves around the creation of an accurate and self-consistent virtual model of a building, adding information about both its structure and behaviour. The end objective is to increase predictability and reliability of the project by fostering communication between involved parties. BIM can be intended as both the building model considered as a digital set of data and as the model updated throughout the life cycle of the building. BIM has been available for more than a decade; nonetheless a standard usage is rare throughout the design stages. The passage of information is often limited to exchange generic geometric models in the most common formats.

In a coordinated design it is the building model that has the greatest information value; therefore the exchange of models is necessary. In a reasonably short future, in order to have a larger diffusion and a most effective usage of BIM, the models will have to be directly exchangeable among different disciplines. For this reason the concept of interoperability has grown side by side with BIM, and a promoted, and still under development, format for exchange between models is Industry Foundation Classes (IFC) (Coates et al., 2010).

The models allocated in a building model file may be organized in systems, made by spaces and elements. Parameters associated to the different systems describe them, as well as containment hierarchies to describe connections. There is no unique way for the data link among building elements: this will restrict the extent of information exchanged. The manual implementation of the mapping may become arduous in case of models with many parts.

4. Implementing BIM in Construction Phases

The benefits of Building Information Modelling (BIM) implementation in construction have been widely acknowledged. Construction projects pass through several phases in which BIM can be utilised as a tool. To integrate BIM effectively into all construction phases, a comprehensive approach is needed. This section discusses how BIM can be used in different construction phases and interacts with the actors in this process.

The discussion illustrates that successful implementation of BIM must also consider the collaboration of the key participants in each stage, and to this end, proposes a protocol for effective collaboration practices (Georgiadou & Georgiadou, 2016).

BIM efficacy can be realised if it is implemented and used during all construction project phases. Thus, BIM implementation in construction projects can be divided into three main categories: pre-construction, construction, and post-construction. The pre-construction phase of a construction project is crucial for planning and resolving issues before they arise on site. Cognitive use of BIM in the design coordination phase results in a less turbulent construction phase. Similarly, early BIM implementation in the design phase can introduce less change which leads to fewer construction problems. Early stage problem-detection via BIM also reduces the probability of abortive work. Thus, using BIM at an early stage of a project will create direct benefits for other participants involved.

Successful delivery of a construction project is difficult due to the large number of variables involved. Of the total capital cost on projects, 70% is subsequently spent on building maintenance activities. BIM technology allows construction projects to be delivered more effectively by creating digital models for construction and facilities management. The role of BIM in construction has developed to focus on enhancing project outcomes, enabling safer construction processes, reducing costs and time and improving the quality of design and construction. In construction, BIM is used in project tracking to help manage project progress and project costs. Similar research has also identified the benefits of BIM at the construction phase to manage the allocation of resources.

4.1. Pre-Construction Phase

As the initial stage when project planning begins, the pre-construction phase is crucial for setting a strong foundation for BIM implementation and use. In this phase, BIM can be used to enhance project planning and design coordination. It is instrumental in visual representation of the relationship among equipments and facilities in addition to the daily changes. Early collaboration among the parties involved promotes effective decision making and identification of potential conflicts between what is constructed and the project model. It is crucial to get involved in the pre-construction and planning stage since decisions that can affect the realization of design will be made during the time. By doing it ahead might ease the process by helping to ensure that the design decisions are based on actual parameters. Decisions are taken from design and proactively driven to the field through planning construction ranging from schedule update and detailed coordination to detect in-field conflicts, thus improve project and delivery quality (Nisa Lau Santi et al., 2018). The method helps in creating a more intelligent model for effective visualization. BIM tools can also forecast exploration needs and provide reports on the condition of the project site, before visiting the site. As a result, effective planning of exploration will ensure an increase in cost savings and performance. In the pre-construction phase of development projects, there is a thorough investigation of the current situation, preparation of detailed construction schedules for the appropriate design, cost estimations and plans for obtaining funding. Scheduling and cost data has been my primary focus. BIM usage is limited in of obtaining the possibility for adoption to construction projects. The results of this study indicate that the use of a BIM approach in developing projects: (i) increases accuracy in cost estimation and (ii) presents a developer-view development mechanism to evaluate the feasibility of the unprecedented project. During the planning, process better visualization of the design decisions is important to understand and to communicate. Upon finishing their drafting work based on papers. BIM is used only by having prints and abstracted specifications. When considered in general, project drawing and specification data are voluminous sources that can easily call confusion. An information file shall be maintained showing with greatest detail and clarity every step of action or decision regarding work changes. All intramural BIM coordination participants are responsible for executing the BIM success plan and for meeting project milestones. The number of site crewmen and subcontractors on site and their duties should be communicated clearly for efficient site and scheduling. Distribution technique type and origin point should be used while confirming activities as effective communication channels among project participants.

4.2. Construction Phase

In the construction phase, BIM technology is essentially used to perform the design validation to real-time project tracking and monitoring tools in which the construction processes can be checked/compared with the design of the model to ensure that the execution of the project is in line with the design intent (Anton Kivits & Furneaux, 2013). The process of checking the physical construction rendering compared to a 3D BIM model can be seen in bend and twist detection in substructure installation process at the silo station. The development of 4D-like tracking and monitoring tools which can provide an alert for possible wrong construction rendering in the substructure erection of bridge equipment is anticipated to reduce the number of misinterpretation of construction drawings and the implementation of the project will be increasingly accountable. In the current project, the implementation of those 3D models requires the use of BIM software, reviewed after modeling. However, BIM software is more powerful used in an office or good signal spot condition. The field BIM software integration in which the model can be opened on a tablet and zooming in and out can be done at the same fidelity is not available at this time. Thus, it is vital to develop and integrate the field BIM software so that the installed construction can be easily checked on the go, improving the communication in the project site of the project. This tool is used by the civil work contractor in the CPG project stage 2 at the viaduct section. The design of the 3D model of an architecture, structure, or MEP can be used to derive the construction sequence on a 4D model. This tool can then be used to optimize resource management, field operation, and construction cost etc.. The implementation of 4D modeling in the project will make a means to develop the schedule model of the project as well as providing a program of work to the user departments or the contractors so that the project can be executed in the most effective way. The tool is used to structure the Works Divisions in the CPG project. Since the project implementation in 1992, BIM or now so-called BIM tools have long been used in the construction industry, further development of those BIM technologies integrating with the newly developed software/applications should be made so that more significant benefits are obtained on projects.

4.3. Post-Construction Phase

The post-construction phase of a BIM-enabled project is the key to obtaining the most advantage from the large-scale and granular information generated as a by-product of the construction. Throughout the project life cycle, BIM functions as an all-encompassing depository for building operation and maintenance facts and is a handy source of information for building operators and facility managers (Michal & Blanka, 2019). By visualizing the building in minute detail, it helps to comprehend it more thoroughly. Facility managers can swiftly access space-related information by clicking on the model and at the same time capturing supplemental data to update the as-built conditions and conduct operations. As-Built conditions could be continually updated in the BIM model by comparing the model to the physical assets and recording the deviations. This can also be expanded to include operations that could trigger changes in the model. A good example is the detection of a water leakage event that would prompt updating of the model with respect to the affected area as well as indicating vicinity objects that could have been damaged. The gathering of inspection and performance data is linked to the collection of IoT data on building properties. The BIM model will assist in managing the collected data therefore contributing to priority fixing of most critical equipment. Online sharing of requesting fixes could be a feature integrated with the original model that would visualize the current condition and enable filling in of the request directly in the model. The solid information collected could also be utilized for post-performance analysis of assets when contemplating renovation or replacement. In association with collected IoT data, it will help to recognize where the design process failed to meet expectations or where systems get overburden. Such an analysis will lead to improved practices and adjustment of maintenance plans. The model can be utilized for conducting exploratory assessments analyzing sustainability aspects. For example, shading analysis at current conditions can aid in energy management. This type of analysis could be helpful in identifying where to plant new trees or other shading devices to reduce energy consumption of cooling systems or to improve indoor comfort. Accurate record-keeping facilitates legal compliance and provides comprehensive information meeting all reporting needs (Chen & Tang, 2019). Political regulations and obligations change as a result of accidents, e.g., fire in tall buildings. BIM is a powerful instrument to store any sort of documentation, images, and specifications needed to support legal compliance. All decisions and activities are monitored and data will be permanently stored in the model.

5. Collaborative Platforms and Data Sharing in BIM

Building Information Modeling (BIM) is expanding into a paramount role in the AEC industry as an integrated platform of combined technology, collaboration, and working processes. Even though the technology is well-founded, the building processes rely heavily on technology, collaboration within all existing professional disciplines, and smooth international communication. Consequently, the need for improved and assured collaboration and data sharing goes far beyond a matter of efficient integration and adequate communication within BIM or any BIM platform (Lai & Deng, 2018). Several platforms have been developed to address real-time sharing, analysis, and collaborative editing within architectural models.

Real-time cloud platforms are commonly used for the sake of an Internet-based cloud, offering file sharing and hosting services. In recent years there has been the disruptive arrival of cloud storage with real-time file access synced across many devices. Uptake is based from individuals through to businesses who frequently have multi-user access to cloud-based desktop files, ideal for collaborative working groups (Redmond & West, 2015). The massive adoption of cloud based metrology ability linked to real-time data with graphing, geo-location, and time-stamping is leading to a new dawn of metrology practices and e-technologies. Cloud computing, being non-device specific, has seen a similar adoption across stationary and portable products across many of the internet's services. Real-time cloud server hosted applications are being adopted from personal productivity suites through to specialist software dedicated to creative, scientific, and E-commerce sects. Traditionally, data exchange for construction design and management happens mostly in a 2D vector or raster format because of a lack of interoperability capability of heterogeneous software tools. The file format and file structure standardization of BIM, however, provide promising support for multidisciplinary collaboration. To facilitate it, some cloud-based development allows web-based data visualization and analysis has been developed. Such technologies support to upload and manage data in the cloud and provide data sharing, services on the web. However, the process of data exchange between different BIM software cannot be supported. Instead, as a workaround, manually data to IFC standard format using a certain software tool, and then using other software tools to read and extract the model/model data is performed on the cloud.

5.1. Cloud-Based Solutions

Construction industry operations have been changed by cloud technology in the midst of the mostly used business solutions including collaborative models of development and reliable workload automation. Cloud-based solutions have effectively revolutionized data accessibility by the stakeholders of a project. Most significantly, in the case of Building Information Modeling, people could affinitize different partners to both view and gain shared data in a real-time environment while concurrently not consuming money and time to rebuild it in a different place. There are manifold advantages to managing project data with cloud-based tools over conventional methods. Within one secure virtual storage environment, everyone is on the same page, mitigating or even erasing difficulties in data sharing. Relevant models and documents are updated simultaneously and communicated efficiently across the whole team, eliminating barriers to information flow (Abanda et al., 2018). Communication, rare due to the specificity of formats in particular software or model versions, becomes simple. There is no more time wasted adapting incoming data to the platform appropriate for the existing project tools. A separate advantage is the flexibility in gaining remote access and thus the ability to work with a large amount of ever-increasing spatial teams located in different parts of the globe. Generalized cloud-based solutions are examples of tools that allow for the creation of one large linked data environment. They offer many possibilities of working with it, e.g. hosting projects as a CDE that allows immediate display of models, generated views or anything else in the cloud. Data readers are another prominent feature often included in this kind of software. Among other options, the possibility of assigning tasks and responsibilities for information creates a digital twin in a virtual and augmented reality view. Another benefit of some platforms is interoperability with IFC data exchange, which significantly increases the number of supported file types. In addition to the many attractive features hosting large project structures, often criticized for the security of stored data, most often equivocally, in fact transform it into a full-fledged digital fortress. Certain storage repositories are designed only for projects based in BIM, with an emphasis on environment security and advanced search options with near-instant access to data. The cloud is also described as a promising platform for providing the economic basis for many developments in the construction industry. Scalable cloud solutions are adapted to both small and well-developed enterprises working in this relatively conservative niche. Therefore, it is extremely important to properly train teams in a way of working that is effective locally but not slowing down by including access and collaboration in the cloud. As pointed out, global trends in construction industry operations have already been transformed by cloud-based solutions. With the constantly growing base of provided tools, this element of an approach to shared data will become not only a recommendation but necessary to maintain the continuity of business.

5.2. Interoperability Challenges

A number of interoperability challenges exist in terms of sharing information between different BIM platforms. Several stakeholders face issues in their collaborative work across different BIM software as the data is exchanged between these software in different formats (Lai & Deng, 2018). Consequently, model representations, and other BIM object properties, references, schedules and specification details are distorted or even lost. Moreover, some users must re-enter model data during the creation and editing of BIM objects, which then becomes a duplicate effort. With regards to that, the efficiency of traditional construction projects has not soared greatly and much of the industry is still considered inefficient. This contrasts strongly with the rate of productivity gains achieved in other industries over the last few decades. But there is a ray of hope and that is sector can improve, indeed revolutionize, its performance.

The overarching goal of this paper is to move this process forward. It aims to do so by assessing the current state of Industrial Foundation Classes (IFC) implementations, and the broader field of interoperability. There is a specific focus on the accommodation of flexibility in the BIM at the interface of the civil structural and geotechnical disciplines. Cleared funds and political commitment have recently been found to move towards an open standard-based collaborative platform, yet in line with the principle that knowledge is power, it is the desire to scrutinize the standard they were committed to produce (Arayici et al., 2017). The best vision of researchers, suppliers, and contractors is sought in seeing how this platform should be; what it should be able to do, or allow to be done, by users at the operative coal face; and what would be needed to afford sensible integration of the design and construction models.

5.3. Data Management Strategies

The objective of a BIM is not to produce just one master model but, also, to facilitate communication and knowledge management of design, construction, and operation processes. The more ambitious objective is to store and maintain the comprehensive knowledge of those processes and activities, thereby enhancing the ability to maintain assets efficiently and extending their useful life to the maximum possible (Anton Kivits & Furneaux, 2013). The challenging point is how to store and interact with this wealth of knowledge. It will have mountains of data written and related to all the inherent properties of geometry and/or functioning of an asset. It could also include all types of information concerning obsolete and/or critical systems and equipment, as the generic objects inserted in the 3D model usually need to be adapted for each specific instance. Difficulties would be found in accessing this data in real time for the right purposes. A possible way to address this, however, would be to create different versions of the model, simplifying it and filtering the data not absolutely necessary at that moment. Keeping shared data in a seamless and accurate manner is known as data governance. As the information collected at each step through the ED model is shared among partners, it is essential that some pre-determined rules about its treatment are present. To achieve this, different tools and methodologies can be used. One starting point is to format the database in an elegantly organized way. Another way to enforce governance is to give access to the model information just through recipes of information linked within the model. Designing an automatic check for several properties using scripts in the model viewer software enables one to overlook and correct such mistakes. Finally, a training program is another way to uniformly perform model checking. It is of the utmost interest that all team members perform such activities with the same proficiency. On average, companies experience a difficulty transferring knowledge or procedures. Therefore, it is key to ensure that every involved member is fully capable to handle all necessary operations in the software. Better pace of work, decision-making, and project outcomes will be seen as a direct result. On top of the above strategies, a data backup plan is essential. Steps should be taken to guarantee that all data is consistently saved. As all project and site plans, surveys, and models are kept in the database, due diligence will be performed to avoid risks. Finally, an emergency recovery plan should be put in place in the unfortunate event of data loss.

6. Conclusion

The architecture, engineering, and construction (AEC) industry affects the daily lives of all human beings, most notably through the built environment, which is essential for shelter and essential services. In recent years, there has been a substantial drive to deliver these structures in more sustainable and efficient ways. To provide these services, the industry works through the stages of design (including planning and landscape), preliminary design, detailed design, construction drawings, construction, and operation (including renovation, restoration, and demolition) (Georgiadou & Georgiadou, 2016).

The advent of building information modeling (BIM) tools and technologies has had a transformative - if still to be fully understood - impact on how the industry operates. Somehow less noticed, however, has been the transformative impact of this broader changes on the tools and software used by the professionals. This is equally profound, and risking being overlooked.

The effective use of BIM technology is more than a matter of employing the right software; it fundamentally requires the adoption of new working processes and collaborative approaches. BIM institutionalizes open and transparent working practices, and as such is recasting the architect’s role as that being characterized as only the ‘author’ of a project. This new context has been quietly creating a fertile ground for the expansion of a new breed of internet-based companies managing digital content in a way that closely emulates creative disciplines, and now allowing a much more fluid and parallel design process possible (Papadonikolaki et al., 2018). The practices are supported by a combination of affordable off-the-shelf software and tailored online services, grounded in common data environment approaches. This alignment is a harbinger of more extensive changes ahead, as the common CDE standard now embraced by the level 2 BIM matures.

References:

1. Lewis Foster, L. (2008). Legal Issues and Risks Associated with Building Information Modeling Technology.
2. Papadonikolaki, E., Leon, M., & Mahamadu, A. M. (2018). BIM solutions for construction lifecycle: a myth or a tangible future?.
3. Kummala, I. (2017). Tekla Structures komponenttien nykytila-analyysi - Kuinka käyttäjäkokemusta voidaan parantaa.
4. Coates, S. P., Biscaya, S., & Rachid, A. (2018). The utilization of BIM to achieve prescribed undergraduate learning outcomes.
5. Coates, S. P., Arayici, Y., Koskela, L. J., Kagioglou, M., Usher, C., & O' Reilly, K. (2010). The limitations of BIM in the architectural process.
6. Georgiadou, M. C. & Georgiadou, M. C. (2016). Building Information Modelling in UK Construction Projects: A State of the Art Review.
7. Nisa Lau Santi, E., Zakaria, R., Aminudin, E., Saar Chai, C., Yusof, A., & Muhammad Fatihi Hafifi Che Wahid, C. (2018). A Review of application building information modeling (BIM) during pre-construction stage: retrospective and future directions.
8. Anton Kivits, R. & Furneaux, C. (2013). BIM: Enabling Sustainability and Asset Management through Knowledge Management.
9. Michal, F. A. L. T. E. J. S. E. K. & Blanka, C. H. U. D. I. K. O. V. A. (2019). Facility management and building information modeling during operation and maintenance.
10. Chen, C. & Tang, L. (2019). BIM-based integrated management workflow design for schedule and cost planning of building fabric maintenance.
11. Lai, H. & Deng, X. (2018). Interoperability analysis of IFC-based data exchange between heterogeneous BIM software.
12. Redmond, A. & West, R. (2015). The use of cloud enabled building information models – an expert analysis.
13. Abanda, F. H., Mzyece, D., Oti, A. H., & Manjia, M. B. (2018). A study of the potential of cloud/mobile BIM for the management of construction projects.
14. Arayici, Y., Fernando, T. P., Munoz, V., & Bassanino, M. N. (2017). Interoperability specification development for integrated BIM use in performance based design.

Chapter 04: Understanding Simulation Types in Revit

1. Introduction

Simulation is essential in architectural and engineering design, evolving from 2D to 3D solid and parametric modeling, particularly in Building Information Modeling (BIM). This shift improves simulation quality in processes like Architectural Lighting Studies, Structural Analysis, MEP (HVAC), and Sustainability (LEED Certification). Advances in technology have changed simulation integration with design, with software like Revit offering parametric modeling tools to validate designs and predict performance. (Rafsanjani & Nabizadeh, 2023)Simulations also enable analysis of topological changes in models regarding structural, MEP, and environmental impacts, crucial in traditional design practices and fully supported by Revit. However, effective simulations rely on accurately modeled structures. Revit's data generation for drawings doesn't prioritize absolute accuracy, which can lead to overlooked fabrication needs and inaccuracies in models. Such discrepancies hinder simulations from realistically representing the final structure, whether built or not. (Mahmoud et al., 2024)Thus, precise modeling should be a primary focus in BIM practices alongside addressing Risks and Issues through simulations. This research on simulations in Revit aims to serve as a primer for understanding various types used in BIM. The Introduction lays groundwork for readers, emphasizing simulations like Lighting Analysis, Energy Analysis, and Heating & Cooling Loads Analysis, crucial for Architectural, Sustainability, and MEP project elements. The simulations play vital roles in decision-making and optimizing designs in both presented studies. (Liang et al., 2012)

In addition to performance validation, simulations in BIM environments like Revit support interdisciplinary collaboration by enabling shared insights between architects, engineers, and sustainability experts throughout the project lifecycle. This shared digital environment fosters a more integrated design process, where simulation results can be used to refine material choices, construction sequences, and energy strategies collaboratively. Moreover, as buildings become increasingly complex, simulation serves as a key component in lifecycle assessment, allowing stakeholders to anticipate long-term operational impacts such as maintenance requirements and resource consumption. The integration of simulations with data-rich models not only enhances early design decisions but also contributes to more resilient, adaptable, and cost-effective building outcomes. As digital twins and smart building systems evolve, real-time data feedback from sensors will further enhance the predictive power of simulation, bridging the gap between virtual modeling and real-world performance.

2. Overview of Simulation Types

This chapter summarizes methodologies for energy, structural, flow, and lighting simulations for BIM beginners. It highlights the importance of simulations on outcomes and presents design optimization strategies. Selecting suitable simulations based on project requirements is essential, as Building Information Modeling enhances design efficiency. While some firms utilize proprietary software, design teams often choose simulations tailored to their needs. The framework covers simulation types, their calculations, and impacts, offering recommendations and exploring issues in "check analysis," noting the reliance on built-in servers or third-party software for detailed analyses. (Kumar et al.2021)

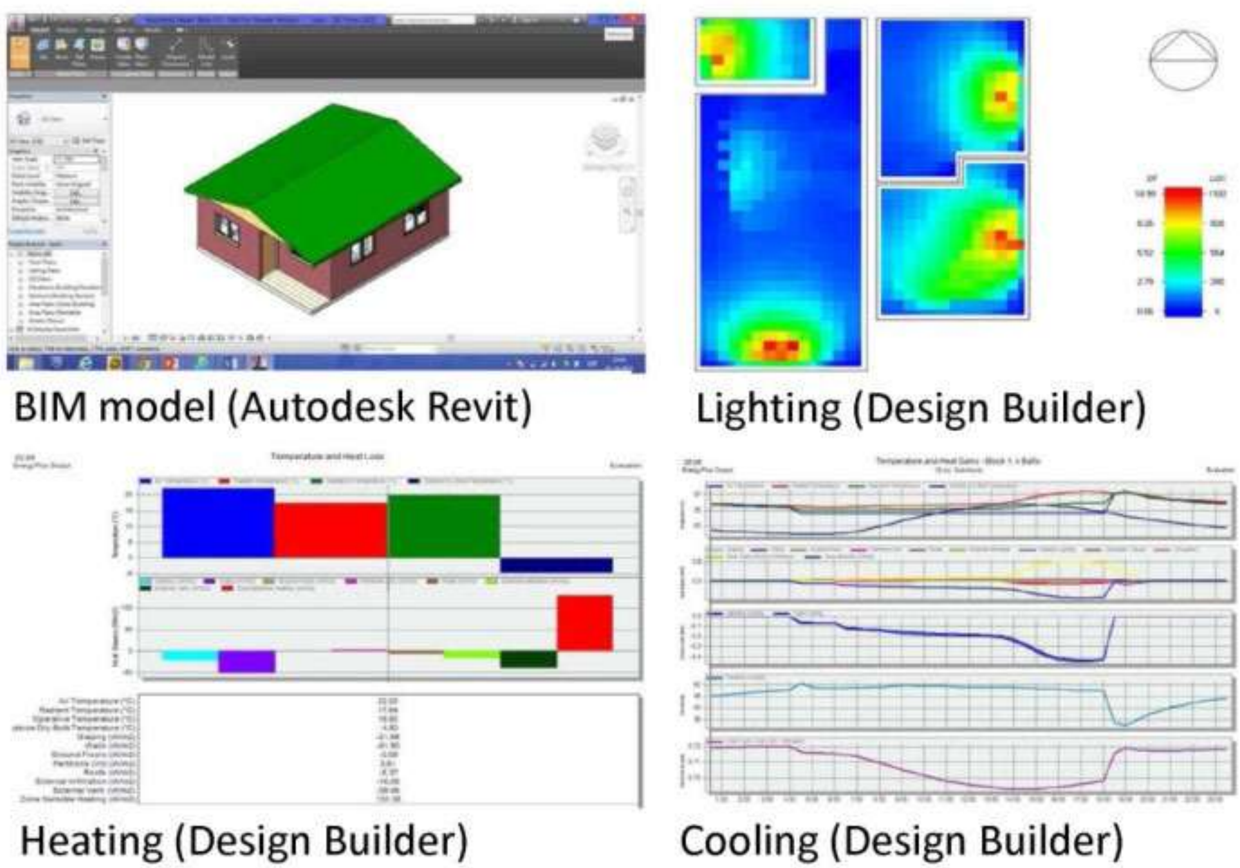


Figure 01: Examples of simulation type

3. Energy Simulation

Energy simulation, specifically building performance simulation (BPS) involving energy, light, and water, is integrated into advanced building information modeling (BIM) software like Revit. Unlike other simulations focused primarily on geometric appearance, BPS in Revit relies on detailed object information, including heat transfer and lighting. This energy analysis enables users to assess overall energy consumption, component distribution, heating and cooling impacts, and environmental implications. Energy simulation is crucial for enhancing building performance, prioritizing energy efficiency, essential for budget management and sustainability. Numerical representation of energy consumption is an effective predictor of a building's overall usage. Revit employs two main methodologies for BPS. The first is a built-in simulation tool for conducting conceptual energy models, necessitating advanced analysis of materials and construction zones, internal gains, and climate data.

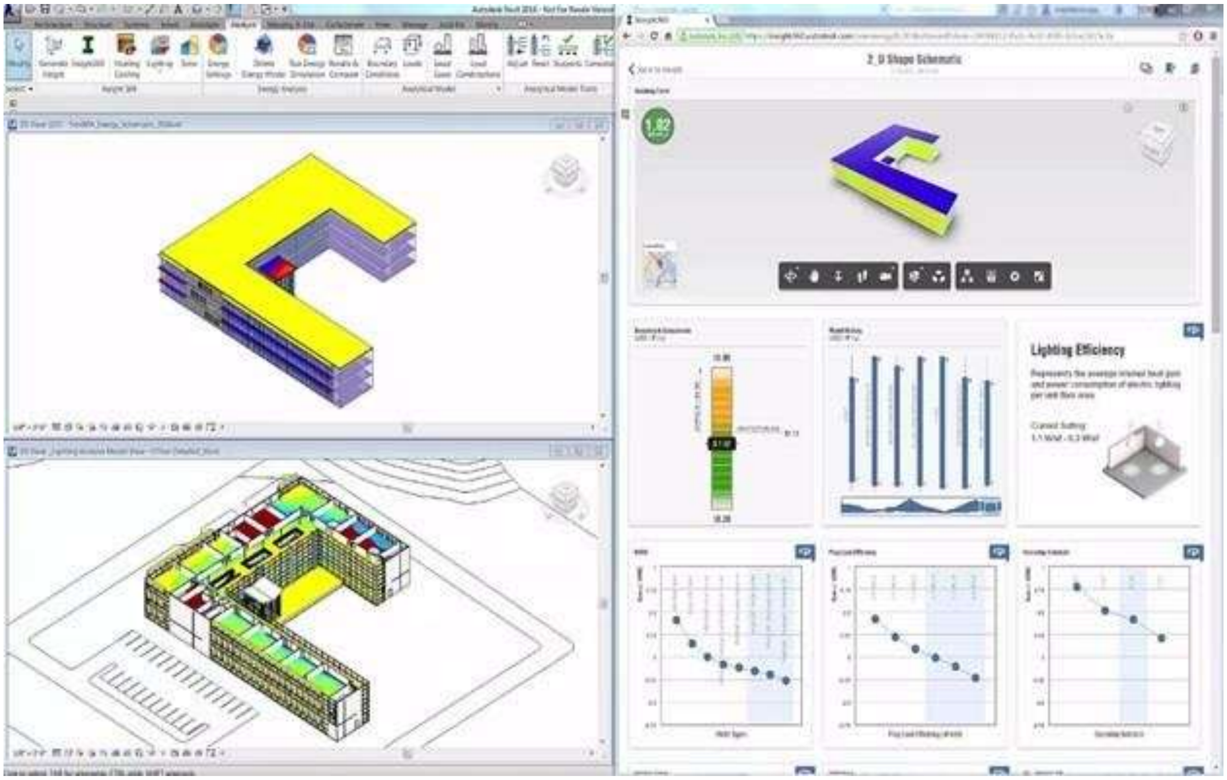


Figure 02: Whole Building Energy Analysis in INSIGHT for Revit Credit Autodesk

The second approach uses interoperable formats such as EnergyPlus, which receives building descriptions in text format, facilitating interaction through Integrated Environmental Solutions (IESVE). This platform coordinates energy simulations in Revit, sending all essential data for further analysis. A case study illustrates these methodologies, focusing on a residential house with a basement and attic, reflective of typical construction. Following the simulation, the energy analysis results inform design strategies for reducing heating and cooling consumption. This includes a comprehensive overview of the energy simulation process in Revit, geometry and property adjustments across different house designs, energy consumption variations, and insights related to energy codes. Additionally, the study contrasts results from erroneous and accurate construction models. (Liang et al., 2012)

3.1. Importance of Energy Simulation

Simulation is vital in aviation, space, and automotive fields due to safety and cost concerns, leading to significant investments in computer-based simulation packages.

However, architectural design has lagged in adopting these analytical tools. Early design simulation with Building Information Modelling is cost-effective, allowing architects to reinvest savings into their projects. Buildings contribute significantly to greenhouse gas emissions and electricity consumption, with a notable share from residential and commercial sectors. As governmental regulations increase, accurate predictions of energy usage are essential for compliance, especially for buildings seeking green ratings. Energy simulation is crucial for these assessments, prompting firms to prioritize energy efficiency and sustainability. A city has launched a sustainable design plan emphasizing carbon neutrality and reduced energy use, underscoring the necessity for architects to address energy simulation to avoid future challenges. By assessing the energy performance of a preliminary residential building through simulation, designers can explore varying designs, leading to informed responses that consider environmental and financial factors. This approach fosters architecture that benefits urban communities with lower carbon footprints, ultimately linking energy resource considerations to innovative architectural practices. (Liu et al., 2023)

3.2. Case Study: Reducing Heating and Cooling Consumption

Most architectural practices employ BIM tools like Revit/Autodesk for design, utilizing simulation add-ons for energy analysis, illuminance, heat and cooling load, and solar exposure. While many focus on early design environmental impacts, few analyze indoor environments and thermal comfort in depth. Using simulation tools and exploring various “What if scenarios” can enhance design optimization. An example of this is a residential warehouse project in Zagreb, which emphasizes collaboration between architects and engineers for thermal analysis. The Trnovec district is slated for about 250 apartments within a 26,000 m2 residential building, featuring a compact design due to construction height restrictions. The east-west orientation was chosen to optimize window area ratios while using discrete windows mainly for aesthetics and not ventilation. Focus remained on indoor thermal comfort, leveraging temperature stratification as a beneficial outcome. Schedule-dependent simulations examined various architect and engineer scenarios. Strategies were assessed to achieve project goals, and significant results were documented, though realization may take years due to urban planning constraints. (Sánchez Ramos et al., 2019)

4. Structural Simulation

Simulation analyses are widely used in the Revit interface for various purposes. Structural simulation enables assessment of material performance and load-carrying capacity through static or dynamic force and heat-flow simulations. These involve physical dimensions of objects and materials, with methods including solid, mesh, and point element objects, each with material properties and varying connections. Connections and constraints may exhibit elasticity, damping, or flexibility, interacting according to physical laws of motion and energy transfer. Revit structure supports mesh faces or solid objects where internal element forces are applied. However, external forces like moment, shear, or axial cannot be directly simulated, though they can be indirectly represented as distributed forces at polygon vertices, leading to unrealistic sharp load-transmission corners. Load-bearing simulations are crucial for structural alignment, ensuring buildings can support loads throughout their lifespan.

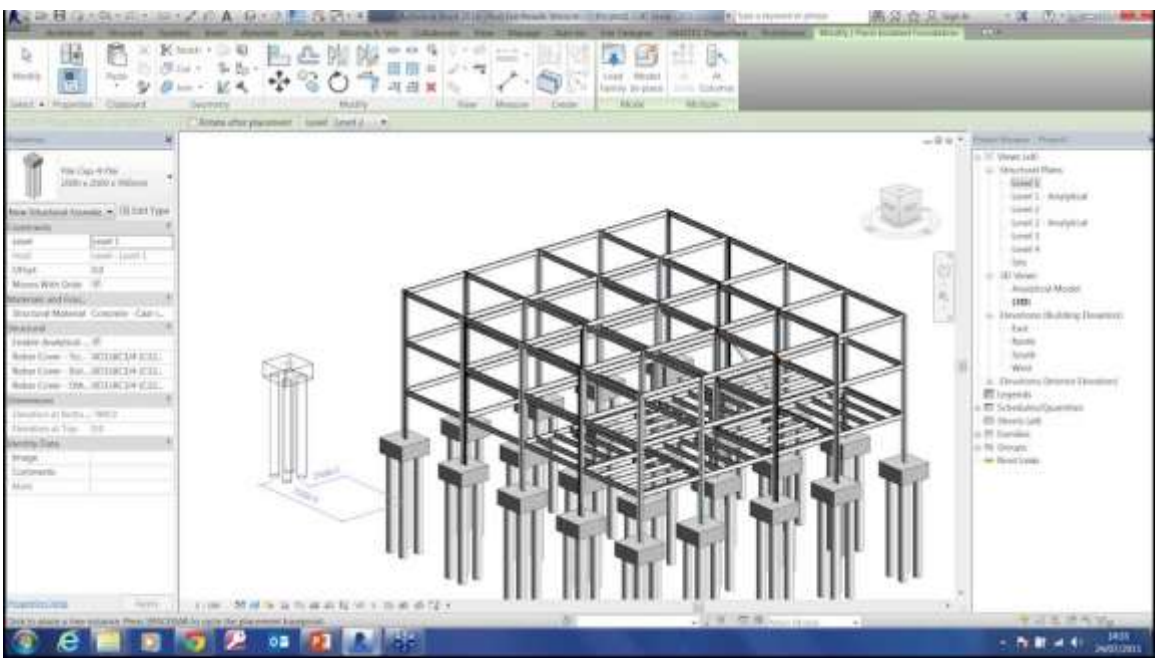


Figure 03: Structural Simulation

The BIM development environment links design accuracy to construction standards, emphasizing the need for architects to consider not just aesthetics and function but also compliance with regional safety standards. Research into beam stability indicates optimal results arise from proper materials in multi-layered systems, limiting deflection. Layer division is vital, as fewer layers generate more bending energy. Additional factors, such as wall height and lateral restraint, reveal that simple design changes can lead to complex outcomes. Using solid elements instead of multiple masses on wall C did not yield anticipated results, highlighting the unpredictability of simulation outcomes and the necessity for experimental design modifications in appropriate contexts. Employing focused case studies can enhance understanding and predict design modification outcomes. (Liang et al., 2012)

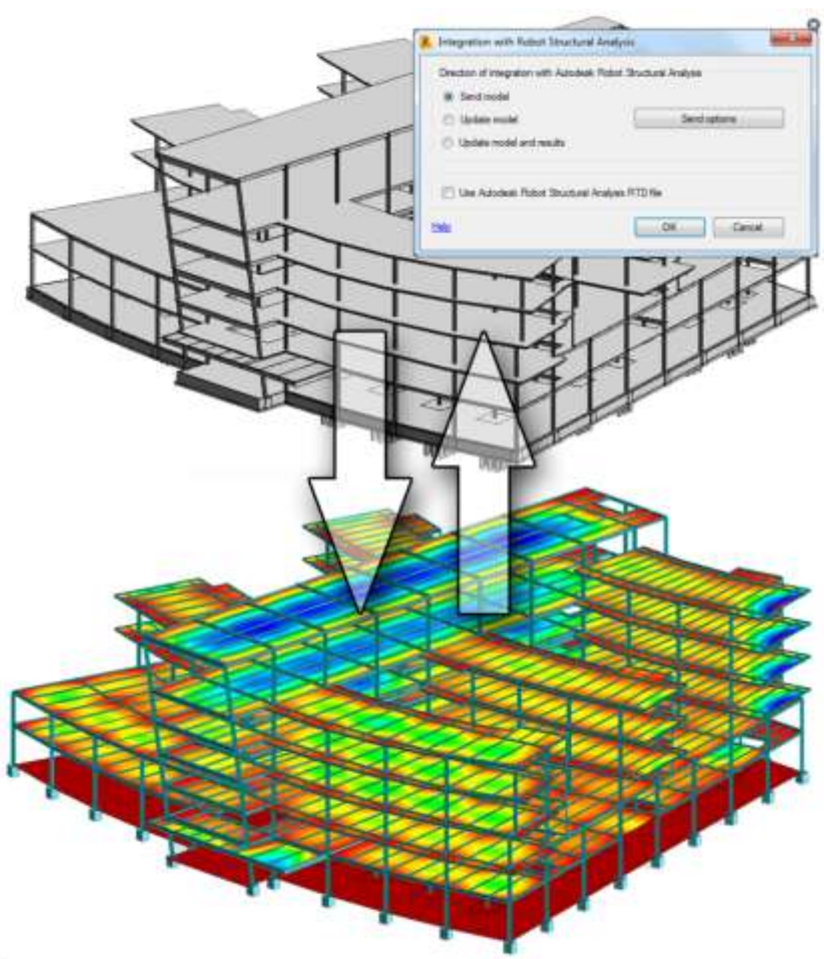


Figure 04: Structural Simulation 2

4.1. Importance of Structural Simulation

Constructing structures that are both durable and aesthetically complex is a major challenge facing the architecture, engineering, and construction (AEC) industry. Traditionally, buildings were conceived and designed in sequential phases—discouraging the sameness of design and engineering elements. However, as architectures evolve to incorporate complex designs that push the limits of engineering and material science, documenting the virtual design and engineering becomes increasingly critical. With the maturity of BIM as a vehicular container bridging the disciplinary schisms between construction, engineering, and architecture, now there is a value to provide a unified vision for the documentation of AEC projects. In this context, an application-oriented computational framework is presented that allows integrated simulation between the architectural design and engineering disciplines. The approach leverages on Revit as a flexible BIM platform where traditional and simulation-oriented parameterization are represented through the gbXML language. The particular case of thermal, illumination, acoustics, and structural simulations within the context of a prestigious AEC project for the city of Zhengzhou, China is presented, highlighting strengths of this framework that is flexible for multidisciplinary applications for complex structures (Liang et al., 2012). The paper concludes with an examination of existing limitations and some forthcoming directions for enhancing the framework.

4.2. Case Study: Load-Bearing Wall Stability

Background: Ultra high-performance concrete coupled walls are increasingly used in high-rise buildings, with their structural performance reliant on the interaction between walls and frames. A three-storey coupled wall-frame building is modelled and analysed using a finite element package. The model includes a detailed consideration of quality issues. An influence model with a capacity spectrum is applied for progressive wall yielding in the time domain. In the frequency domain, the site response from the footings is transferred to the walls' tops, determining the inelastic response spectra of wall-top forces.

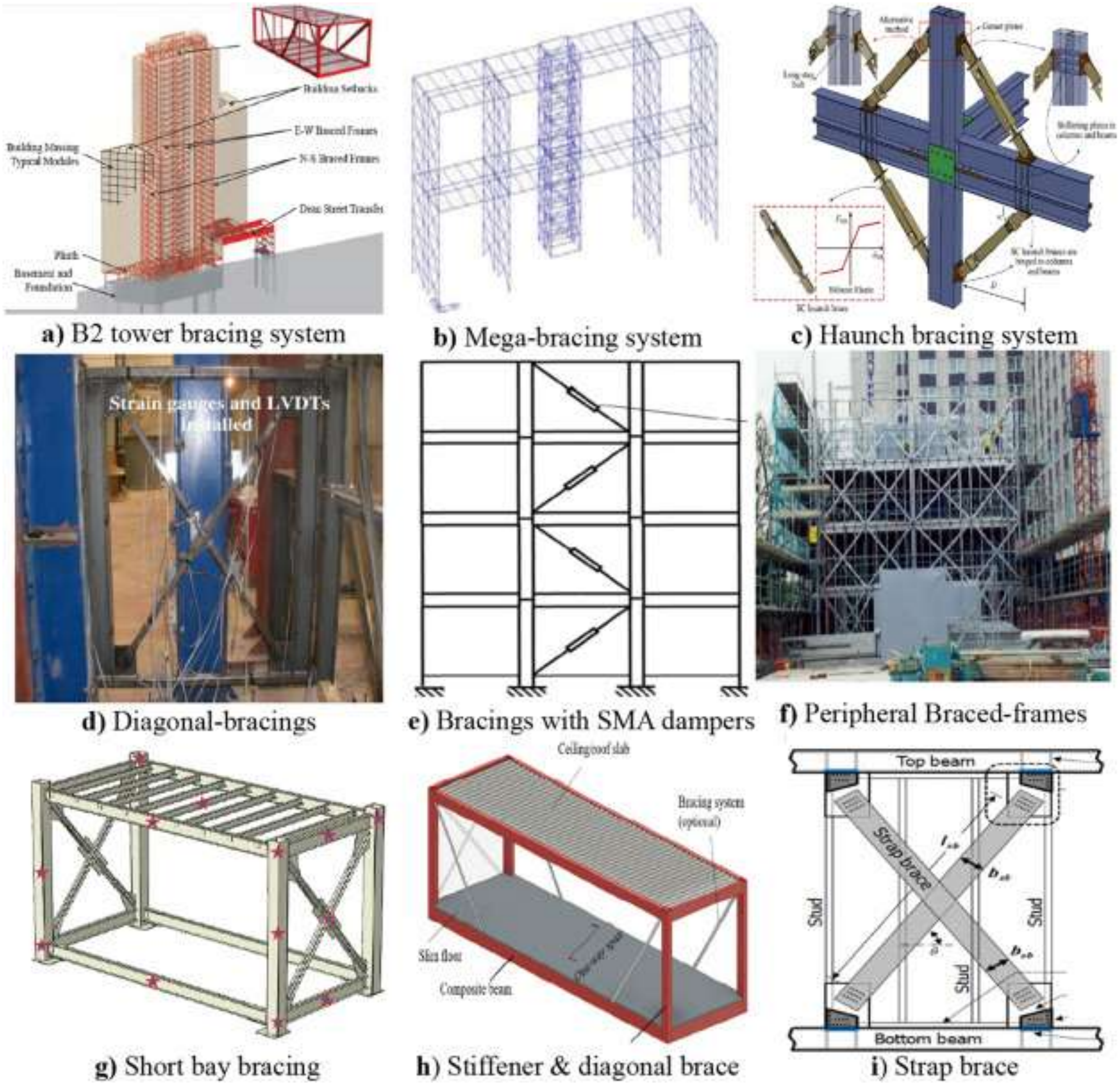


Figure 05: Lateral Stability System

These spectra are then evaluated at the base and plinth levels using code-based response spectra for global performance assessment. Quantitative assessments of modelling uncertainties are conducted through model comparisons. The addressed model quality issues are crucial for future similar numerical analyses in earthquake engineering, an emerging area of seismic protection that has not been extensively researched. Introduction: Building design involves unpredictable factors such as structural aging and material reactions over time. However, Building Information Modeling (BIM) allows extensive analysis of these elements prior to construction. Simulations can predict effects like glare from glass roofs or weathering under heavy rainfall. Building analysis tools are now as essential in project design as drafting software, offering comprehensive insights into a project's performance under various pressures throughout its lifespan. (Han et al., 2021)

5. Flow Simulation

There are various simulations in Revit for optimization and analysis, such as resistance, light, shadow, noise, thermal performance, and ecological efficiency. Flow simulation analyzes fluid movement, particularly air distribution in buildings to ensure fresh air supply and effective ventilation. This is crucial for safety during emergencies, such as ensuring evacuation routes are viable in fires. Designers may assess air movement in schools or investigate egress safety in shopping malls, adjusting designs to comply with safety codes.

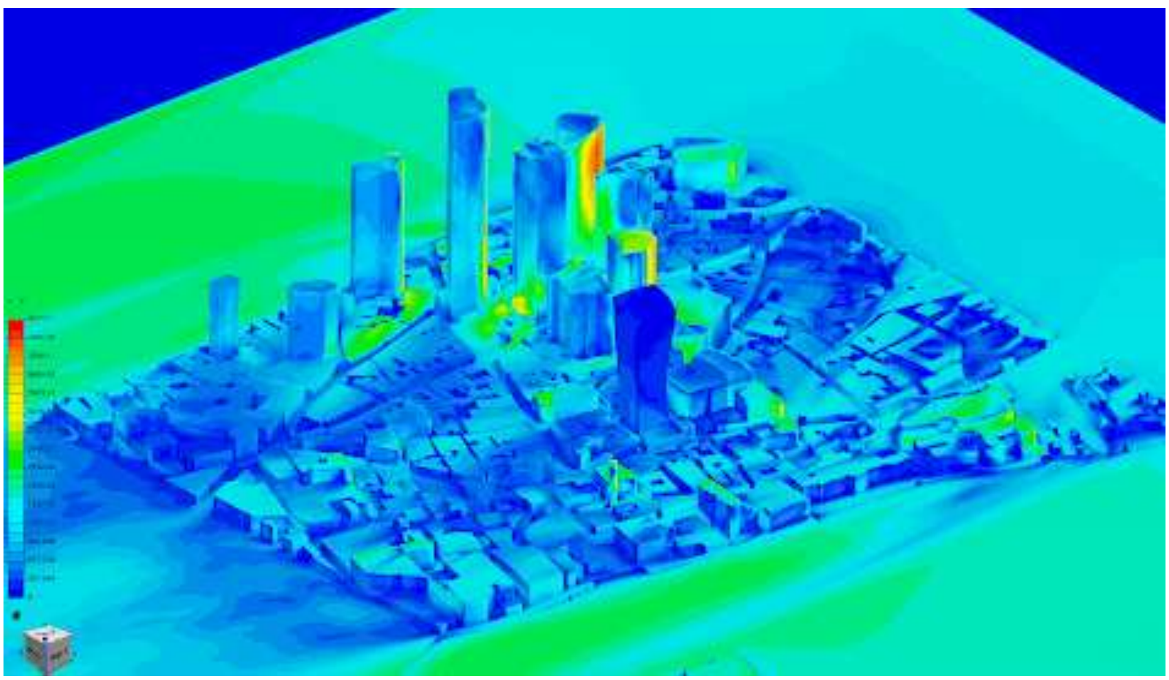


Figure 06: Revit Workflow for Microclimate Simulation

Flow simulations identify building ventilation needs, optimize window arrangements, and enhance pedestrian safety during windy conditions. They are vital for occupant health, as inadequate ventilation can lead to indoor air pollution. Early evaluations of ventilation systems through flow modeling can prevent energy inefficiency. Egress safety is critical during urban fires. Studies show that wind isolation affects city ventilation. A Hong Kong case study modeled hazardous air toxin releases and found that spatial designs like Footbath Basin improve safety. Simulations identified that even minor footbath adjustments could extend escape times during hazardous conditions. This research aids urban planners in designing safer, health-conscious structures. (Liang et al., 2012)

Moreover, integrating flow simulations with local climate data and real-time environmental inputs can further enhance the reliability of design decisions. Revit, when linked with external environmental analysis tools, allows designers to simulate how seasonal wind patterns, humidity levels, and temperature fluctuations influence indoor air quality and circulation patterns. This integration supports climate-responsive architecture and helps in reducing reliance on mechanical ventilation systems, thus lowering energy consumption. Additionally, simulations can model human behavior in emergency scenarios, providing insight into evacuation bottlenecks and the psychological response of occupants under stress. By simulating both environmental forces and human dynamics, architects and engineers can create buildings that are not only structurally and environmentally optimized, but also responsive to the complex realities of occupant safety and comfort.

5.1. Importance of Flow Simulation

Flow simulation is crucial for building analysis, particularly with air movement due to changes like heating and cooling, pressure, or temperature differences. It enables testing models to understand how environmental changes affect airflow. Analyses include duct systems, exhaust flow, HVAC forces, and air quality, all essential for efficient air management, which can improve indoor air quality. Room designs can control air movement for comfort, utilizing shapes like curves to benefit from natural airflow. Safety is a key concern; airflow analysis helps manage smoke during emergencies and protects against dangerous airflow patterns. Such assessments are vital, as improper designs can pose significant hazards. Instead of complex physical experiments, specialized software can validate designs against safety and efficiency criteria. While building systems encompass ventilation, the broader picture involves considering natural drafts and forced airflow. A comprehensive design needs to integrate these systems, focusing on how they operate collectively. Temperature, lighting, sound levels, and their impact on airflow and comfort must be taken into account. (Lopez, 2023)Proactive airflow considerations are crucial during design, as modifications post-construction are challenging. Airflow is one of four systems analyzed in building performance, alongside thermal, lighting, and structure. The interplay of these analyses may require trade-offs in design concepts, emphasizing the necessity of integrated airflow considerations. In conceptual design, a broad understanding of the relationship between building form and performance is vital. Initial analyses should contemplate how airflow will affect the design. Shape optimization and early model tests can clarify form impact before deeper analysis. Subsequent performance evaluations should build on earlier airflow results to ensure cohesive design. (Liang et al., 2012)

5.2. Case Study: Evacuation Strategies

This case study on Evacuation Strategies for a building design project examines flow simulation's role in assessing pedestrian movement. Flow simulation informed both the building design and alternative strategies. It identifies congestion areas and optimizes exit routes. The study evaluates evacuation paths through simulations of various layouts, considering factors like internal room design, door placements, and building dimensions. Simulations factoring in furniture and egress locations provide insights into pedestrian behavior under normal and emergency conditions, revealing congestion points crucial for fire safety. By analyzing each scenario, a strategy for enhancing pedestrian movement is developed. After evaluating the existing layout, several congestion areas in egress routes were identified and addressed in newer designs, achieving a significantly safer arrangement. (Wu, 2018)

6. Lighting Simulation

A revolution in architectural design has emerged with Building Information Modeling (BIM), allowing the simulation of window-based lighting in 3D models. The daylight effect influences human visual perception and significantly impacts architecture. "Daylighting design" refers to the management of natural light distribution and its aesthetic effects. BIM's light modeling module helps analyze lighting distribution by defining luminous flux fields in various locations. Lighting distributions can be graphed from different perspectives. Two key approaches to addressing lighting issues in architecture include designing efficient lighting systems and optimizing enclosed spaces, balancing natural and artificial light for sustainability. Building light quality is measured by specific quantities like illuminance and daylight factor. Designers utilize simulation tools to forecast indoor lighting conditions, moving from traditional static diagrams to advanced computations using the Radiance simulation engine that models light reflection and transmission. For example, architects of the Hong Kong Museum of Art implemented simulation software in the design phase to calculate gallery light diffusion, influencing the atrium's design. Since natural light impacts visual perception, predicting its effects is crucial in architectural planning. Despite advanced simulation tools, outcomes remain uncertain, making experience valuable. This paper explores how simulations combined with design principles led to unique architectural solutions that would have been challenging to realize otherwise. (Liang et al., 2012) (Yu et al., 2014)

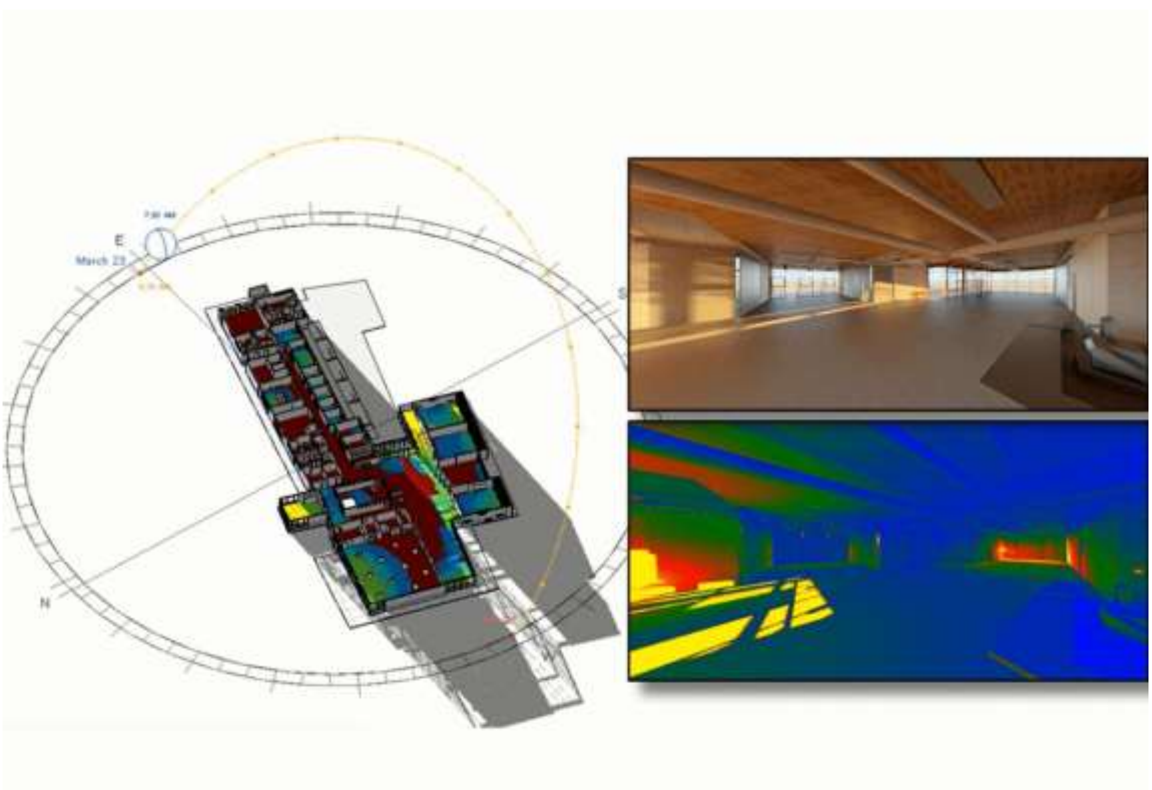


Figure 07: Lighting Analysis for Revit expands to include Custom Daylighting - Building

6.1. Importance of Lighting Simulation

Building energy consumption due to lighting accounts for 40% in indoor spaces. As the demand for quality living rises, individuals seek effective lighting sources. Proper lighting enhances appearance and experience while ensuring energy efficiency and compliance with building codes. Interior lighting design is vital for user comfort, emphasizing the necessity for accurate lighting simulations in the design phase. These simulations aid in making informed decisions about fixture placement—considering aesthetics and technical aspects, which are often challenging to gauge using traditional methods like spaced readings or visual renders. Lighting options can reveal potential maintenance issues and areas of excess energy consumption. Simulations also demonstrate how lighting reacts to motion and changes in color and intensity throughout the day. They raise awareness of the environmental impacts of lighting choices, potentially promoting more sustainable sources and reducing light pollution. Ultimately, lighting simulation serves as a tool for innovation in unconventional architecture projects.

6.2. Case Study: Maximizing Natural Light

Project XYZ focuses on office spaces in a compact urban European district, emphasizing daylight maximization while controlling sunlight from adjacent buildings of similar height. This study assesses daylight penetration from the East by varying orientations and window placements, revealing that the Northern facade provides superior daylighting. Daylight simulations of 20 design options (10 per orientation) were conducted through a BIM model and mapping tool, significantly cutting calculation time. The emphasis was on office spaces, as other areas demand less daylight, and relocating offices from the core had minor impacts. Low-quality daylight only reached private spaces within the core. Rendering simulations indicated energy-saving opportunities by decreasing artificial lighting and heating. Adequate lighting conditions influence aesthetics and psychology, making daylight essential for well-being. Historically, lighting concerns have grown during the design phase instead of post-construction. The building has a simple cubical form with a glass façade, avoiding unnecessary sun breakers. Simulation outcomes prompted adjustments in orientation and window placement, with the best results achieved from North orientation and 90-degree window positioning in options 5 and 6. Effective collaboration identified optimal building settings, yielding up to 45% savings by balancing heating costs with reduced artificial lighting. Detailed lighting simulation analyses suggest that best daylight intensity arises from nearby shorter East buildings, particularly with North orientation and precise window placement. (Miri and Ashtari2022)

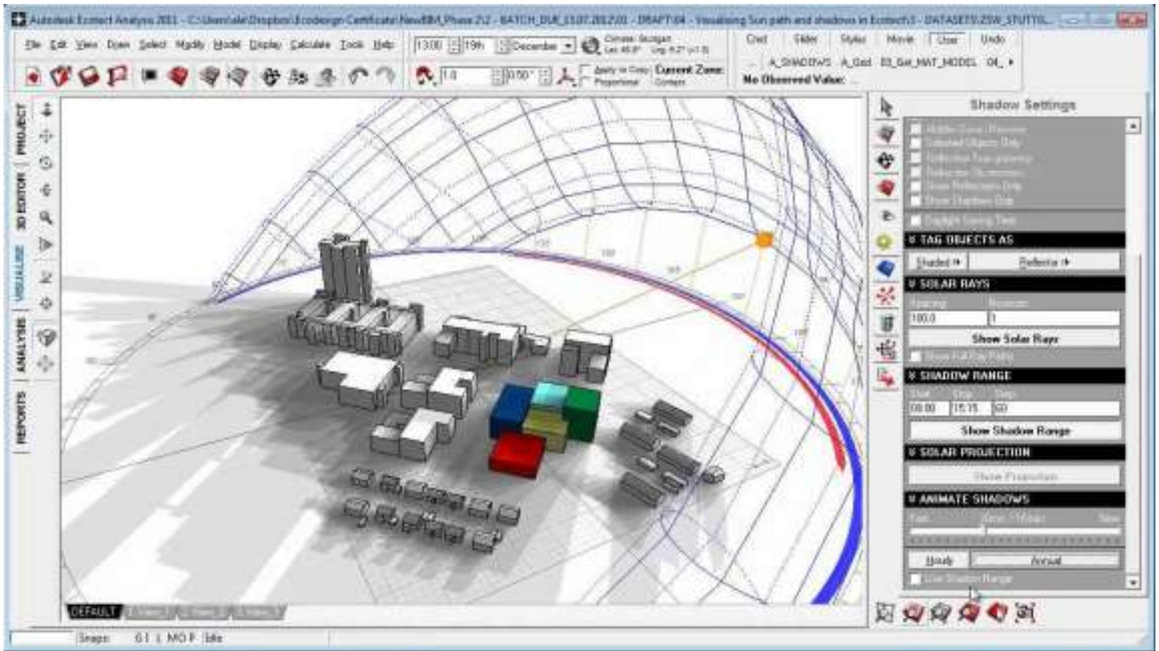


Figure 08: Solar study in Revite

7. Comparative Analysis of Simulation Types

A comprehensive comparative analysis of energy, structural, flow, and lighting simulations is conducted to assist designers and engineers in understanding the appropriate application of each simulation type. The methodology revolves around key performance indicators that evaluate different simulation approaches, highlighting strengths, weaknesses, scenarios, and case studies. The interactions among simulations and their combined benefits are investigated, offering insights on which simulations are necessary for a deeper comprehension of design concepts. In the digital era, producing rational and effective analysis of design concepts quickly and understandably is crucial. With the rise of Building Information Modelling, various simulations can be employed through intelligent models. This analysis focuses on frequently asked questions regarding the timing and effectiveness of simulations, as well as the impact of design variables on simulation success. Years of simulation experience contribute to the establishment of key performance indicators: pre-treatment effort, cost-effectiveness, model implications, interpretability, and the ability to refine and re-run simulations. This framework aids in evaluating energy, structural, flow, and lighting simulations for design concepts. The comparative analysis demystifies the pragmatism of different simulations, and the methodology, results, and discussions are organized into sections covering strengths, weaknesses, scenarios, case studies, and future directions. (Hossain et al.2023)

8. Conclusion

There are various types of simulations available in Revit that are useful in attaining sustainable and effective design outcomes of a proposed design. One of the most commonly used and most basic is energy analysis, which looks at the heat energy in the design model and the flow of energy through heat gain and loss on surfaces and transferred to the surroundings. The effect of heat gain and loss on surfaces can be influenced by materials and volumes of spaces. For instance, the type of glazing or roof to wall ratios, window to wall ratios, and other design decisions are made based on the proposed energy analysis result. But, the workflows for simulations are varied with the type of simulation.

An architect may have a decent understanding of energy analysis, but not structural or flow analysis. This makes sequence design a vestibule partition opaque construction concrete, by simulating and refining the massing on the energy, structure, and fluid on an increase product. Then if consultation is needed or desired, the sequence design logic could be explained and results could be shown to visual learners, whereas traditionally the explanation of the sequence design logic could be offered, but the result would be less communicable. Next step is to simulate and refine the proposed design using the additional types of simulations, including but not limited to: the wind, acoustic, and the lighting mitigation the occupancy and the light path. Once the design will simulate using the intended set of simulations, high resolution models can be imported and further refined based on results from the previous simulations. Finally, the in-progress proposal should be tested against known, both good and poor, design solutions and refined based on the results.

In addition, simulations in Revit contribute to **early-stage decision-making**, allowing architects and engineers to test multiple design alternatives without the need for physical prototypes. This not only saves time and resources but also encourages experimentation with innovative forms and sustainable strategies. By integrating simulations such as daylight analysis, solar exposure, and thermal comfort, designers can anticipate environmental challenges and adjust orientation, materials, or spatial organization accordingly. These early insights are critical for meeting performance targets, obtaining green certifications like LEED or BREEAM, and ensuring occupant well-being from the earliest phases of design development.

References:

1. Rafsanjani, H. N. & Nabizadeh, A. H. (2023). Towards digital architecture, engineering, and construction (AEC) industry through virtual design and construction (VDC) and digital twin. Energy and built environment.
2. Mahmoud, M., Chen, W., Yang, Y., & Li, Y. (2024). Automated BIM generation for large-scale indoor complex environments based on deep learning. Automation in Construction.
3. Liang, N., Xu, H., & Yu, Q. (2012). Research on the simulation framework in Building Information Modeling.
4. Kumar, P., Debele, S. E., Sahani, J., Rawat, N., Marti-Cardona, B., Alfieri, S. M., ... & Zieher, T. (2021). Nature-based solutions efficiency evaluation against natural hazards: Modelling methods, advantages and limitations. Science of the Total Environment, 784, 147058.
5. Liu, W., Shen, Y., & Razzaq, A. (2023). How renewable energy investment, environmental regulations, and financial development derive renewable energy transition: Evidence from G7 countries. Renewable energy.
6. Sánchez Ramos, J., Guerrero Delgado, M. C., Álvarez Domínguez, S., Luis Molina Félix, J., José Sánchez de la Flor, F., & Antonio Tenorio Ríos, J. (2019). Systematic Simplified Simulation Methodology for Deep Energy Retrofitting Towards Nze Targets Using Life Cycle Energy Assessment.
7. Han, D., Kalantari, M., & Rajabifard, A. (2021). Building information modeling (BIM) for construction and demolition waste management in Australia: A research agenda. Sustainability.
8. Lopez, S. L. (2023). Optimizing fire emergency evacuation routes in underground coal mines by exploring dynamic network flow: Case studies and analysis.
9. Wu, C. (2018). A SYSTEM ARCHITECTURE FOR THE INTEGRATION OF SMOKE PROPAGATION SIMULATION, EVACUATION SIMULATION, AND BUILDING INFORMATION MODELING.
10. Yu, X., Su, Y., & Chen, X. (2014). Application of RELUX simulation to investigate energy saving potential from daylighting in a new educational building in UK.

11. Miri, M., & Ashtari, E. (2022, November). Implementing a Digital Solution for Architectural Daylight Analysis in BIM Based Projects by developing a new plugin. In IOP Conference Series: Earth and Environmental Science (Vol. 1099, No. 1, p. 012013). IOP Publishing.

12. Hossain, M. K., Toki, G. I., Kuddus, A., Rubel, M. H., Hossain, M. M., Bencherif, H., ... & Mushtaq, M. (2023). An extensive study on multiple ETL and HTL layers to design and simulation of high-performance lead-free CsSnCl3-based perovskite solar cells. Scientific Reports, 13(1), 2521.

Chapter 05: From BIM to CIM: Extending Digital Models to Cities

Introduction

The complexity and spatiality of the urban environment challenge how it is understood visually, either through traditional 2D means or more complex 3D visualization methods. The complexity of cities has increased tremendously, not just from physical objects, but also from deeper data and processes. Urban simulation models have matured considerably; most models apply a GIS approach to their 2D platform, yet with the growth of more powerful computers it is now possible to look at more advanced models to allow the development of the wider urban process. This will create an even greater use for a 3D model of the city beyond visualisation. Similarly, a simple volume model of the city can miss out on many processes that occur below ground and increasingly in the air.

A more complete model of the city is not just advantageous for a wider understanding. It is more wanted by developers, planners and designers. The term City Information Model (CIM) has been proposed for such a system to underline the difference from the simple 3D city models of a BIM. Complementing CIM, is the concept of a city dashboard (CD) to allow effective communication of a city model to non-experts in urban simulation model. This is particularly important for scenarios or policy making. Stress testing of the CIM shall be with the function of a city dashboard showing the effect of an outbreak of a fatal disease (Tah et al., 2017).

2. The Concept of CIM (City Information Modeling)

The traditional method of urban planning faces challenges in generating a holistic overview of the development of cities, especially large cities. The rise of a City Information Modeling (CIM) concept offers new insights for developing a city level data set. A discussion of the basic principles of a CIM, and some of the technological applications that are emerging around the globe are included (Tah et al., 2017). Also included is an examination of the urgent need to develop the concept of CIM fully, and adapt it to handle urbanization challenges in the coming years. The benefits of adopting such innovative methods to establish a smart city also are considered finally.

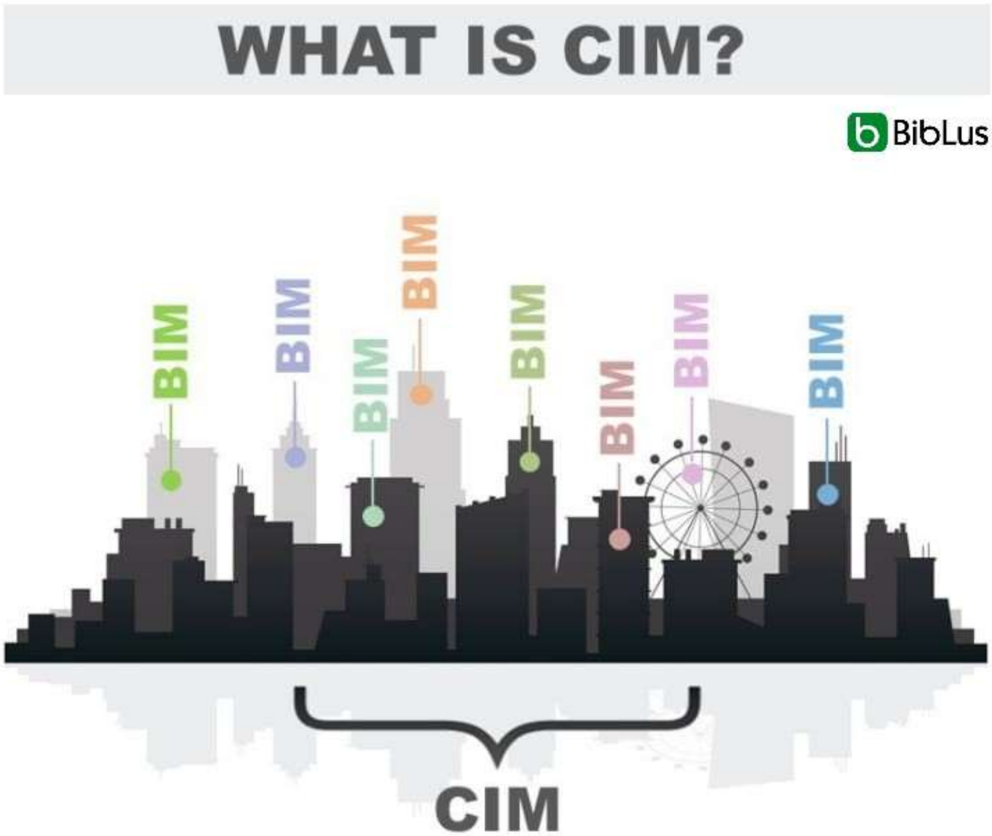


Figure 01: From BIM to CIM

CIM can cover the entire city, or a large part of it, and represent all the components that constitute a city, including buildings and infrastructure. Most importantly, the CIM is based on a common 3D geocoding model, and the components of this model are identified using the City Geography Markup Language (CityGML). This model must include surface model Digital Elevation Model (DEM), land use, population distribution surface, and 3D building models to encode the semantic building, structure, and building footprints according to the defined level of detail (LOD) (Xu et al., 2014). The CIM provides a new approach to represent, analyze, and simulate the city, and it is also a new platform that can integrate and display all sorts of planning and managerial information. Compared with the traditional method of urban planning, a CIM method is more conducive to providing a holistic overview of the development of a city. A question is examined of how the Planning Department could change to adopt CIM in the development of Hong Kong. At the same time, consideration is given to the establishment of guidelines and standards for the development of the CityGeodatabase™ model format. All these efforts will help in the goal of establishing smart cities in the era of digitalization and information.

3. Integration of BIM with Urban Planning and GIS

Since adoption of Building Information Modeling (BIM), the digitalization of building-related data has greatly impacted the processes of design and construction. Recently, many architects, engineers, constructors, managers, and operators have been trying to expand the concept and practice of BIM to the scale of the entire city. At the same time, there has been a significant diffusion of GIS software in the incorporation of data and spatial analysis in the urban discipline. The urban planning process involves a multitude of data analysis and design of both the urban environment and the buildings that compose it. As BIM software is able to operate on either individual building, groups of buildings, or urban scales, (Barbato et al., 2018) provided an overview of the current practice models, market developments, and research in the area between BIM and Urban Planning. Systems of GIS and BIM can be combined to better understand territorial phenomena, to enhance the analysis of cities and infrastructures and to manage urban transformations in a more controlled and holistic way.

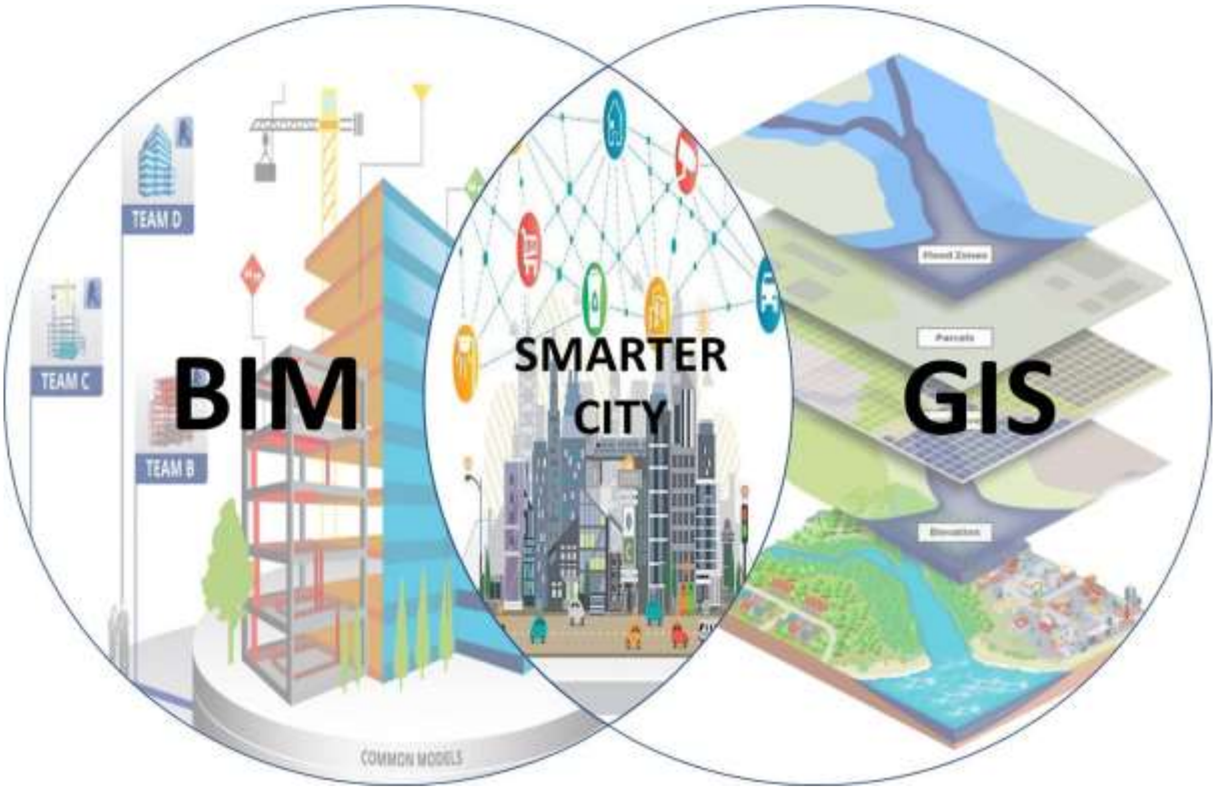


Figure 02: Building Better Cities: The Power of Integrating GIS and BIM

The GIS technology is scalable for the instanced objects and this makes it more suitable to represent citywide phenomena; it can indeed cover a wide range of spatial and thematic scales, from local to metropolitan. Moreover, each feature can be appropriately enriched with a database. In its Early stage, BIM is normally devoted to construction purposes. The models tend to have high complexity and a high level of detail. BIM is better suited to single buildings and more static scenarios. Each of them has its own specific characteristics and this is confirmed by the spread of them in the various fields of the architecture, engineering, construction AEC sector. They can intersect in many applications areas, such as energy efficiency, facility management, maintenance, water supply monitoring, city scale simulations, virtual and augmented reality and the web visualization. But despite these potentials are only starting to be exploited. Integration in the operative or procedural field is still necessary. BIM represent too high quantity of data what is really needed at the scale of a city object. As a response to these expectations, some experiences of the integration practices of a BIM system and a GIS are drawn, to underline the best practices and the most frequent difficulties, both technical and procedural, and the opportunities that can come from this combination for an efficient control of the city-scale transformation processes.

3.1. BIM and GIS: A Comparative Analysis

City Information Modeling (CIM) is an emerging modeling technology that integrates existing modeling methods to model urban buildings and infrastructures. It has the potential to extend BIM and improve urban planning and management. Building Information Modeling (BIM) and City Information Modeling (CIM) focus on representation of man-made buildings and infrastructure in cities, while Geographic Information Systems (GIS) specialize in representing geographical context and analyzing urban land types and uses in a large area, which might suggest a natural way of integrating BIM and GIS into one modeling method. This integrated technique is proposed to be City Information Modeling in this study. In light of the overview of BIM, GIS, and CIM, an in-depth understanding of BIM, GIS, and CIM is given to investigate the compatibility, conflict, as well as the collaboration between BIM and GIS at certain levels. Three cases and two exemplars attempting to integrate BIM and GIS are summarized; moreover, four application scenarios are developed to extend BIM and GIS across the life cycle of urban buildings. Lastly, the future development trend of BIM and GIS is pointed out as CIM.

About 3D buildings, BIM and CIM are characteristically different: a BIM model emphasizes the design aspect of a building, construction process, and maintenance (Ellul et al., 2018). It only provides information with regards of such as material, cost, and precast type. In contrast, a CIM model emphasizes the environment that a building is part of, such as location, simulative weather (e.g., sound, temperature and wind). A CIM model may not care details of a building. A BIM model uses Euclidean data structure that represents a building geometry as a set of universally coordinate-based points while a CIM model may use non-Euclidean geometry structure. Other hand, GIS is good at representing geo-spatial relationships of a large area in one map (Xu et al., 2014). Generally, there are few BIM model viewers equipped with

GIS display functions. Despite the advantages of GIS on Geo-spatial representation, it does not have advanced modeling functions for complex topologies like a BIM modeler.

Features	BIM System	GIS System	GeoBIM
Model Type	Object-oriented parametric modeling	Relational vector-based modeling	Hybrid (Combination of object-oriented and vector-based modeling)
Data Format Support	IFC, RVT, DGN, CAD, SKP	SHP, GDB, KML, GML	IFC, CityGML, GML, GeoJSON
Modeling Capabilities	Clash Detection, Quantity Takeoff, Cost Estimation, 4D Simulation	Spatial Query, Geo-statistics, Network Analysis, Geocoding	Integrated Geospatial Analysis with BIM Tools (Clash Detection, Quantity Takeoff, Cost Estimation, 4D Simulation, Spatial Query, Geo-statistics, Network Analysis)
Time Series Analysis	Limited (primarily 4D simulations)	Time Series Analysis, Real-time Data Integration	Time Series Analysis, Real-time Data Integration
Visualization	3D Models, Renderings	Maps, Charts, Graphs	3D Models integrated with geospatial components (Maps, Charts, Graphs)
Interoperability	Depending on the software, IFC offers broad compatibility	Generally high with standard formats such as SHP, KML	Can be challenging due to the integration of diverse data formats, but improving with standards such as CityGML
Scalability	Highly scalable but can be resource-intensive	Highly scalable, can handle large datasets	Depending on the model types and data formats being integrated, can be resource-intensive
Software Vendor	Autodesk, Graphisoft, Bentley Systems	Esri, QGIS, Google	ESRI, Autodesk, Bentley, Leica

Tasks	BIM Systems	GIS Systems	GeoBIM Systems
Design	Parametric Design, 3D Modeling	Spatial Design, Cartographic Design	Integrated Spatial and 3D Design
Analysis	Structural Analysis, Energy Analysis, Quantity Take Off	Spatial Analysis, Network Analysis, Terrain Analysis, Hot Spot Analysis, Temporal Analysis	Integrated Structural and Spatial Analysis
Coordination	Clash Detection, 4D Scheduling	Spatial Coordination, Network Coordination	Integrated Clash Detection and Spatial Coordination
Asset Management	Lifecycle Management, Condition Assessment, Maintenance Scheduling	Spatial Asset Management, Network Analysis	Integrated Lifecycle and Spatial Asset Management
Planning and Decision Making	4D and 5D BIM (Time and Cost), Scenario Analysis	Spatial Planning, Network Planning	Integrated Spatial and Scenario Planning
Data Management	Data Layering, Parametric Data Management	Spatial Database Management, Metadata Management	Integrated Spatial and Parametric Data Management
Spatial Analysis	Local Space Planning, Site Analysis	Buffer Analysis, Overlay Analysis, Network Analysis	Integrated Space Planning and Spatial Analysis
Collaboration	Shared Model Approach, Cloud Collaboration	Shared Map Approach, Cloud Collaboration	Integrated Shared Model and Map Approach
Construction	4D BIM (Time), Quantity Take Off, Digital Twin	Site Analysis, Network Analysis	Integrated Site and 4D Analysis

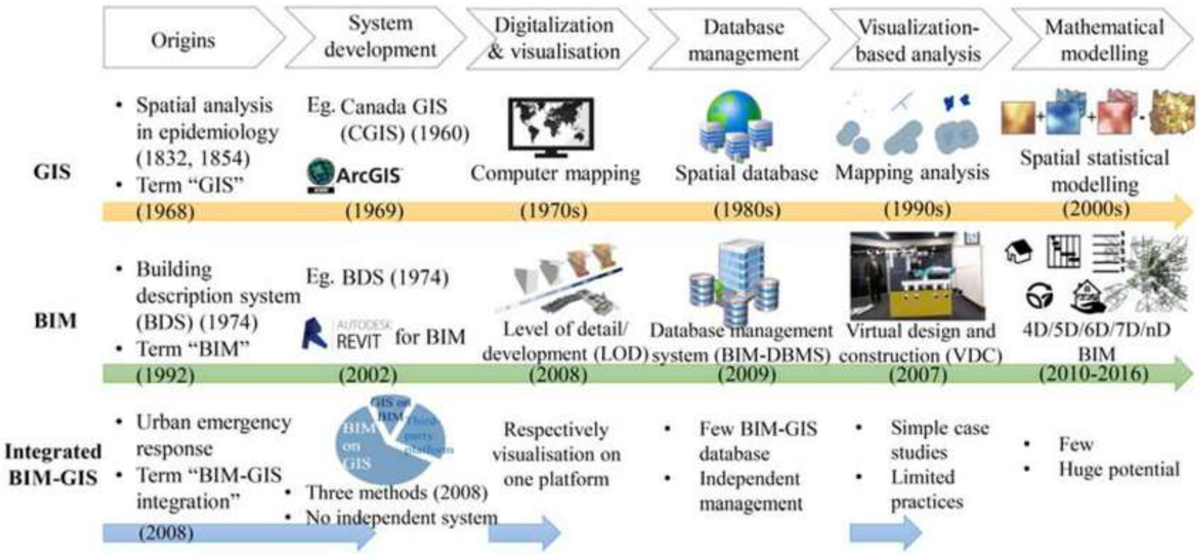


Figure 03: Comparison of evolution progresses of GIS, BIM and integrated BIM-GIS.

3.2. Interoperability Challenges

BIM-based energy analysis tools require detailed geometric information, material properties, and internal loads. Urban energy systems are the scope of city models. EnergyPlus is a whole building energy simulation program developed by the US energy works on a quarterly or hourly basis of the year. The developments enable to link these tools and to carry out energy simulations and sustainability analysis of urban projects in a horizontal dialog among GIS and BIM tools, keeping their data structures consistent both in geometry, attributes and database link. There has been a large increase in the use of BIM and GIS technology within the architecture, engineering, construction, and operations (AECO) industry in recent years. To produce accurate, timely, and safe design, delivery and management of infrastructure assets, public bodies have developed different requirements for use, validation and coordination of digital construction data and information in BIM format. One of the key recommendations concerns the need for public authorities to provide guidance on how they require data in BIM format can be produced by the potential bidders (Xu et al., 2014). However, despite the widespread diffusion of these technologies, the exchange of geometric data and information between BIM and GIS software is hampered by interoperability issues.

The research conducted has found that simple difficulties are hindering the development of procedures that allow a simple transfer, validation and consistency check of the data exchanged in BIM format with external actors after its authorization and validation in BIM level 2 software. Representatives from different stakeholders must reach a common understanding of the information, and consequently, it is necessary to adopt an identification of the information and verification requirements with a clear, consistent and agreed nomenclature between design software. To make sure that all designers work to the "same naming standards", the design software are inventoried that shows readiness for importing and exporting files in open format, capable of both exporting BIM models in IFC format and importing them for further editing.

4. Benefits of CIM in Urban Design and Management

City Information Modelling (CIM) is an evolving paradigmic change, extending Building Information Modelling to cities, where data and knowledge in 3D relationship, gathered from a variety of sources, digital or analogue, are used to predict and manage the future development of the city. The final outcome of CIM is expected to be a simulation engine for territorial monitoring and urban planning, and to better understanding of cities operations and insightful decision making directions. The prediction of spatial development and transactions requires both visualisation and numerical structural analysis with accurate methodology, also encouraged by the advance of GeoDesign, 3D GIS and the opendata policies applied citywide administered authorities. City Information Modelling synthesizes data collected from a variety of sources both digitalized and analogue, in connection to the built environment designated city. City and city related knowledge and understanding is gathered to predict, simulate, monitor and manage the future development of the city. City Information Modelling can provide a medium for better prediction of transaction patterns (Mine Thompson et al., 2016). Policy makers and city owners will be able to visualize the current operation of their city and local market. It may be influential for making strategic and managerial decisions therefore encouraging the relation of stakeholders.

City Information Modelling has the potential of becoming an effective platform for Green Infrastructure network analysis in the case of future offender intervention on development plans. It is not only able to solve complex graphics to numerical interaction problems but it can also be used as a policy strategy for obtaining a sustainable and efficient urban environment in cities. Since the outcome of the CIM concept is to create a new look for the future involvement of cities design, digital transactions and management, this paper is regarded as supportive evidence to the concept that can improve the understanding and citywide approach of cities design and function. At the same time bringing more attention to the current state of cities development and societal and environmental impact which can eventually provide more precise and insightful directives to be carefully monitored and managed. This paper argues that it will be important in the development of CIM model to do market modelling in the metropolitan city area supported by a number of unique citation studies.

4.1. Improved Decision-Making

City Information Modelling (CIM) is a new powerful way to generate tremendous benefits in decisions. Analysts and planners put forward solutions or design urban models which are eligible for further discussion, but it is sometimes called "eyewash with numbers" (Mine Thompson et al., 2016). Analytical professionals who generate those plans argue that decision-makers do not understand them or that decision-makers have not taken the time to understand them. It is not just the arguments, but also a question of visual representation, when everyone involved in planning can see the impacts of the proposals or developments. CIM assists creating integrated data where all information might be accessible (Faltejsek, 2019) and enables analysts, planners, and decision-makers to look at the urban model and see how the multitude of impacts will entail by a particular development or policy. For analysts and planners, to have access to comprehensive data can save time in collecting and organizing information when developing a model, but for decision-makers it provides a one-stop portal which allows them to look up any data of interest on an interactive urban model at any point or time.

City Information Modeling (CIM) can also help looking beyond the current state of information, and assist exploring new development with the incorporation of additional or pipeline data. With a times of austerity at present, it is pertinent to consider how public policy can maximally engender uplift from public and philanthropic investments. There are situations in many cities where an array of policies or investments may be considered for the same urban site. In leveraging investments internally or attracting them from external sources, it could be tremendously advantageous to be able to run dynamic simulations and visualizations of the additional benefits from proposals, such that a coalition of interested parties could be convened. A City Information Model might also be created and opened-up to public discussion well before development is green-lit. CIM is that it allows for scenario planning, so a city council might run a number of different policy scenarios and see which provisionally passes through the most investment hurdles. And at a bare minimum, CIM provides a commercial opportunity for a burgeoning smart city software industry, with the private sector better placed to take advantage of this compared to a miscellany of public and academic research organizations and think-tanks.

4.2. Enhanced Collaboration among Stakeholders

Early adopters of City Information Modeling (CIM) are likely to gain a significant advantage from their experience in setting up a project in the first place (Xu et al., 2014). This invitation industry has a wide production chain including the underwriters, realators, government agencies, contractors, and so forth. The benefits of CIM are substantial. The design and building of a commercial property enabled by CIM places including a shopping mall, a hotel, and an office tower. Both the inter-functional coordination within the same building, and the interaction between the building and the surroundings are considered in the design. Through the CIM-based analysis and simulations, it is shown that the proposed design is viable whilst meeting all criteria. The economic benefits of the proposed build are presented in a business plan. An outline of the taxonomy, structure, modeling methodology, and management of CIM are then introduced. In setting up a project, additional to the normal planning bureau response, demands enhancement along the four aspects of designated land, storages, colossal volumes, and surrounding buildings.

Cities are hubs of human activities. With better opportunities, better services, and better facilities, cities serve as a hub for people to conduct their daily activities. However, with great opportunities come great challenges. These can include the uncontrolled growth of facilities, the omnipresent mechanical noises and toxic gas, and the man-made barriers created by facilities. These problems are traditionally mitigated by the government through spatial design and development planning. The spatial details are not just the external geometry, but also the functions and interactions. Despite the ever increasing amount of data, as a common saying points out, "the water from different sources should be kept separate in the river." Government agencies historically maintain some data private. Consequently, it is not unusual that misunderstandings and consequent legal disputes arise. CIM, by ensuring the transparent data for everyone, could build the trust in the process. Feasible design alternatives in building and civil structure, plus transport are generated and attached to an illustration of the CIM-based scenario modeling.

4.3. Sustainability and Environmental Impact

Sustainability and environmental impact are always positive benefits, so it makes sense that the first areas of use/disruption of CIM are in more successful or developed parts of cities. It is reasonable to expect that, initially, model projects will be those that can show a clear overall benefit in terms of sustainability - the ‘greening’ of a city, for example. This corresponds to the recognition that CIM - like its consumer BIM - is an essentially optimistic process. By concentrating on the benefits and then the successful development of expensive success stories, the potential disadvantages (loss of community fabric, encouragement of consumer culture marriages, etc.) are downplayed or ignored. Whether this optimism is justified - whether there might be interesting and relevant things to say about how CIM might make a city ‘worse’ - is not answered by this paper (Xu et al., 2014). However, it is worth making some efforts to redress the balance.

In general terms, sustainability is a lot more complicated than it might at first seem, requiring a massive effort to force it to “work” in urban design terms. The City of Melbourne argues that “sustainability encompasses a range of economic, social and environmental considerations” but historical interrelation of these terms at an elevated and policy level is too complex. More pragmatically; opportunities for the enhanced placement of trees, greater efficiency in the use of water resources and energy supplies, reduced generation of waste and improved opportunities for recycling, better public transport provisions, and related reductions in traffic congestion - these are benefits to be obtained by reading the model of a city. How, though, do the latest modelling in environmental monitoring, pollution dispersion, and climate change effects sit with the latest urban planning to 'oil' the desire lines? There is a possibility that these (and many others) are better informed decisions, but the potential for abuse - the easy of making the computer "say what you want it to" - is prodigious and pressing.

Melbourne's "2030+ Vision for a Sustainable and Knowledge City Economy" is based on a supportive urban framework of digital models, with many of the tools within a CIM implement already in place. Added value here comes directly from the integration of environmental performance data into the standard database, essentially preventing eco-friendly urban initiatives that might not have been otherwise imagined.

5. Case Studies of CIM Applications in Real Projects

City Information Modeling (CIM) is conceived and discussed in various relevant domains. Case studies of CIM applications through a set of real projects are presented. Different CIM applications in various sectors are showcased and analyzed. Moreover, the lessons learned from CIM applications and some common issues of CIM applications methodologies are also discussed.

A number of successful CIM cases have been reported, such as land planning management, underground infrastructure management, collaborative disaster management CIM, earthquake emergency response, office building Operation Maintenance & Managed (OM&M) CIM, and Infrastructure Facility Management System (INFMS) (Xu et al., 2014). Particularly, the case of collaborative disaster management CIM further demonstrates when disaster happens, the 3D city model will be developed on that. A set of case studies of CIM applications are presented, including detailed descriptions on the CIM solutions and some lessons learned.

City Information Modeling (CIM) constitutes an innovative conception and novel methodology to extend and transfer the Building Information Modeling (BIM) specification to the urban spaces domain. A revolution seems to occur in GIS and computer-based urban design, planning, facilities and civic management paradigm and technology, due to this historic transition point. The concept of CIM with unique advantages is proposed to bring more benefits to the urban construction development and municipal management work (Faltejsek, 2019).

Later, official City Information Modeling (CIM) software will be exploited, developed and put forward for applying that. At the same time, CIM romance specifications and methodologies are proposed based on the CIM software. The revolution will begin after the BIM for CIM.

5.1. CIM in Smart City Initiatives

Cities have been facing new challenges from issues such as climate, changes in urban–rural relationships, and population distribution. Because cities are closed systems covering large areas and are comprised of a wide variety of facilities and organizations, it is necessary to establish a unified method to integrate them into a consistent system. Outside of isolated pilot projects, the establishment of a smart city is a process that has yet to be fully realized. However, it indicates a strategic direction that cities should take in order to involve information technology in urban infrastructure. To achieve this, it is considered to be indispensable to have a methodology to analyze and plan urban environments. Such a methodology can be unified as City Information Modeling (CIM) (Xu et al., 2014). City Information Modeling is defined as an integrated digital model of both the physical structure of a city and urban information, including semantics such as the buildings, roads, bridges, tunnels, railways, pipes, waterways, electric lines and parks. It is developed in a geospatial coordinate system and used as a fundamental tool for the design, analysis, and municipal management of cities.

The smart city describes a wide vision of cities that use digital technologies in their infrastructure to better serve their residents. Smart city projects are taking advantage of CIMs to offer residents a digitally-enhanced urban living experience. This experience includes better physical connectivity with sensors and actuators embedded into infrastructure and buildings that provide real-time data of the city’s state and prompt for actions in city services to achieve better resource management. They made citizens more participative by providing them access to new digital services, and by encouraging them to provide data voluntarily and feedback about public services (Faltejsek, 2019). Services such as mobile applications that provide real time information about public transportation schedules or parking lots show significant use. Services that evaluate parks or public facilities also show a moderate positive feedback. Finally, services providing citizen interaction mechanisms, e.g. to make suggestions, reports or complaints, show a moderate level of use, even though the privacy impact can be an issue. However, all of these rich new digital services are generally siloed and disconnected. They are usually implemented as stand-alone projects set up by individual service providers with little or no common efforts. Some insights and best practices are presented to help those projects improve their digital services, as well as to suggest the emergence of new smart city strategies and projects to take advantage of the unique opportunities brought by CIM.

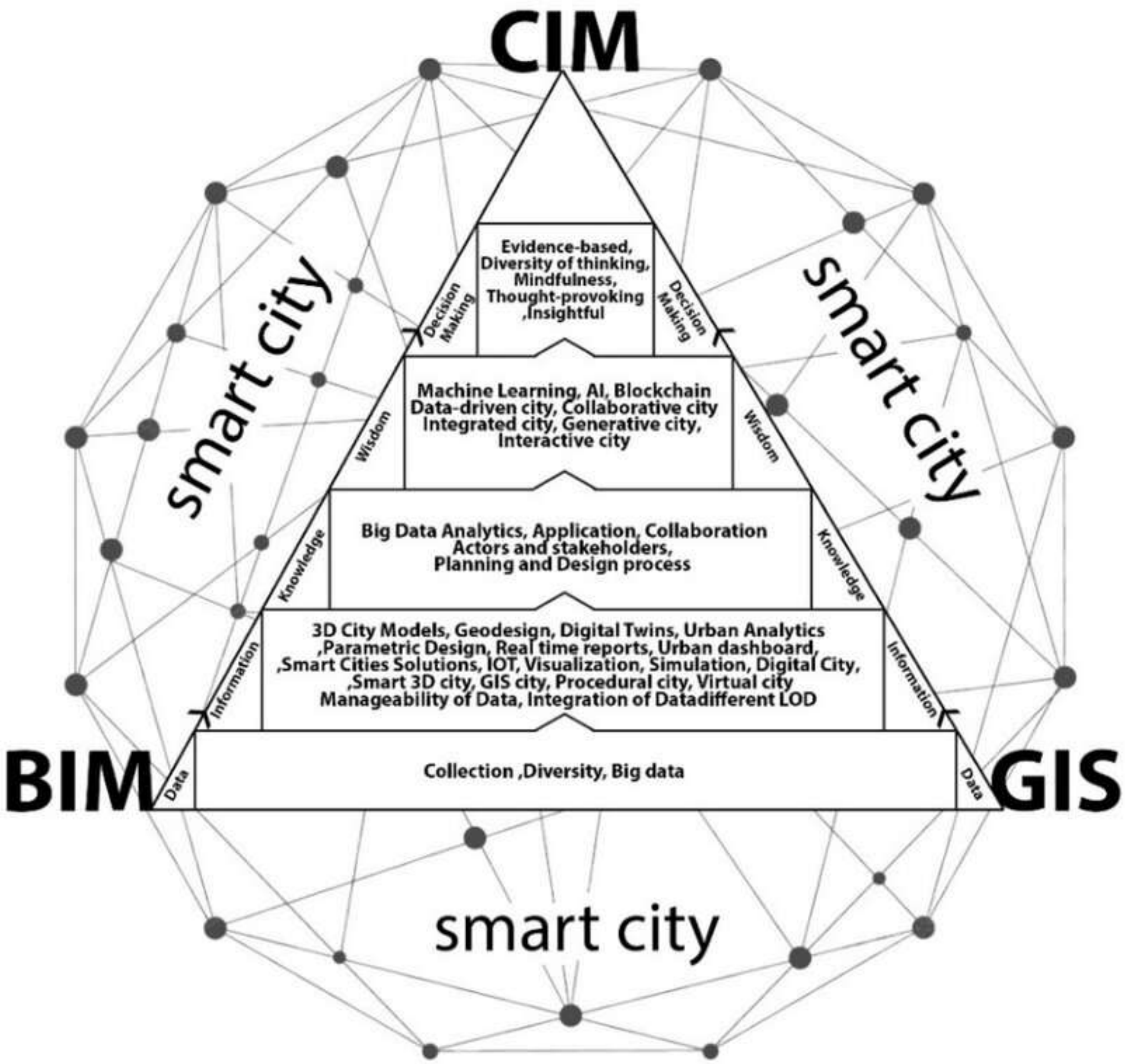


Figure 04: CIM in Smart City Initiatives

5.2. CIM in Infrastructure Development

Urban infrastructure development, including construction, management and maintenance, is an important part of urbanization and involves a series of complex engineering and business matters, regarding policies, standards, knowledge and information (Xu et al., 2014). To plan, design and manage urban infrastructure in a resource efficient, economically competitive, socially inclusive and environmentally friendly manner, a suite of electronic technologies for infrastructure development is being explored. Among these technologies are CIMS, ITRCs, RFID and LiDAR. Digital models, both in drawing and in text, have become fundamental for planning and designing infrastructure development. Their digital nature enables the integration of models, scenarios and geographic information. There is the potential to use city models in infrastructure development under the BIM approach, which allows for increased understanding of urban environments. The aim is to integrate BIM technology into the GIS city model and thus to develop the CIM concept. CIM is a virtual representation of physical objects and it is useful in planning, managing and maintaining objects in the city. The application of CIM in infrastructure development is named as City Infrastructure Information Modeling (CIIM). CIIM is applied in the planning, design and management of infrastructure considered in a project, to respond to the requirement of an efficient use of resources (Faltejsek, 2019).

City Infrastructural Information Modelling (CIIM) is applied in the infrastructure part of urban development projects, intending to improve planning, design and construction and also to help managing infrastructural objects in cities. A pilot scheme focuses on case studies for the CIIM application in efficiency in project planning for infrastructure development. 15 types of infrastructure objects in cities that are involved are introduced. The paper shows a vision of combining CIIM technology in a standardized format with other Geographic Information Technologies (GIT) that are available commercially. Design, construction and monitoring have been studied as the natural applications of CIM in the AEC (Architecture, Engineering, and Construction) field. Coordination among construction teams has been identified as a big challenge considering it requires to develop and adopt new unified approaches usually conflicting with the deep rooted and heterogeneous processes used by the partners involved. In the broader sense, CIM can also be seen as a management tool comprising advanced IT approaches that can be effectively used in the assessment of the sustainability, safety and resilience of constructed infrastructure for a better use and planning of the city and its services. Since the physical conditions of the built environment change over time the last aspect focuses on the post construction time-scale. To this aim, the concept itself of CIM should be integrated into a wider vision of realization of a 'citizen-CIM pact', able to guarantee a fair and effective use of the digital models of the city throughout its life cycle, in a clear and accepted institutional context, between the city administrations, mentioning this concept through the confusing acronym of CIM and the citizens. The institutional context, defining the rulebooks into which the development should be inserted and become effective, actualizes the long term perspective mostly relying on qualitative targets through the realization of a progressive series of projects transferring an increasing amount of wide image model data between the city administration.

5.3. CIM for Disaster Management

Booming urban development and increase in population density not only escalate the complexity of cities, but also exacerbate the risk of disasters. The 2030 Urban Agenda has therefore paid increasing attention to city resilience in the event of disasters, and promoting sustainable urban development is imperative. In practice, digital models can be extended from buildings to cities, as building information modeling (BIM) models can describe individual buildings and city information modeling (CIM) can describe a city as a whole. These models endorse storage and retrieval of city information in a standard and interoperable format. They also contribute to sustained knowledge of the city, which maximizes communication between stakeholders, including decision makers, city planners, engineers, developers, emergency responders and citizens. The City of Dubai has already constructed a digital twin; in other words, a 3D model of the entire city. The operation of this model is known as Dubai 3D Urban Model, which is utilized for verification of compliance with safety regulations and enhancement of service delivery. This approach could help to resolve energy efficiency issues (Xu et al., 2014). However, expansion of the approach to full cities proves challenging, primarily due to the sub-division of responsibilities between numerous government bodies. As a result, a fragmented dataset arises. Simbim™ urban simulator has been introduced, enabling simulation of modelled buildings and cities. As part of this development, data acquisition protocols are being designed to assist in the creation of standard datasets for cities using models (Faltejsek, 2019).

5.4. Lessons Learned from CIM Implementations

Experience from implementing CIM on various projects is distilled into three categories: the stakeholder and communication aspect, the technology development aspect, and the scalability and adaptability aspect. First, the inquiry must be intensified to clarify CIT and CIM to boost the communication with stakeholders and to enhance the application. For the stakeholders only with scant or no rapprochement to CIM, illustrative efforts are particularly requisite for campus project management faculties and local small information technology companies. Tutorial documents about CIM should also be prepared for the upcoming involvement of additional stakeholders in the CIM scheme. The seminars about the impacts of CIM for specific action goals and the methods to access IFC files or create IFC files can speed up the implementation of CIM. Continuing tidings about the development of the materialist world and the impacts of the development of it will arouse more confidence and successful implementation of CIM.

Second, the software is the precondition to visualize CIM models. However, the available CityGML-editing software often makes the CIM-I-generated CityGML, an essential requisite software to develop CIM on its own empirical models, fail in the visualizing conversion. CIM-I far-reaching fails to realize the CIM vision as just GML files and spreadsheet files merely within a single building are output. In inducing the BIM models, however, only the extended exact wording of the needed building elements and building entity is the warranted native approach for both CIM-I and CIM-U as only the native and blockchain software can recognize the exact wording. Ironically, by the implementing of another acknowledged and shared-more-extensively software, the BIM-CIM direct conversion by the 3dcIty4-U can be realized without the need of the extended exact wording, which is a remarkable-late-understanding hindrance for the early five CIM projects. Nonetheless, either C4R or 3dcIty4-U, equal the CIM-I, always executes the predefined building entrances, which is the necessary first amendment useful to the proceeding of all the seven related CIM projects. Third, focusing on the organizational environment and tackling associated complexities, such as the cultural biases of participants and the issues in coordinating among them, will raise the chance of successful implementations of CIM, especially when the implementation environment is a multi-country and multi-organization situation. The overall lessons would be helpful for proponents thinking of further implementing CIM in complex projects.

6. Challenges and Limitations of CIM

Due to the privacy and security concerns of urban information, the aggregation of detailed information in CIM may face big challenges to implement. Even if the private buildings belonging to many different stakeholders in the same city are collectively modeled, the CIM model is expected to be utilized in common. Thus, the private information or data collected for modeling will be inevitably disclosed. To address this issue, the abstraction level of CIM could be raised. Through mapping the real-world entities into different levels of the CIM, the detailed private information could be protected while the general geometrical and semantic properties remained (Xu et al., 2014).

The barriers of technology, including software, hardware, and professional knowledge and skills, must be overcome for the popularization of CIM. To this end, universal interoperability between technologies and application software is needed. Additionally, user-friendly software with simplified operations is demanded so that professionals unfamiliar with 3D information models could easily access them. However, some of the software provided by software vendors is too professional, and hence user-friendly CIM software needed for nonprofessionals is still lacking. The flexibility and diversity of different urban development will limit the popularity of the CIM software.

As a capital-intensive industry, the costs foreseen for state-of-the-art digital technology within built environment processes are, including the development of the model, the ownership of the modeling tools and the performing of the construction, operation and maintenance activities. Therefore, the CIM implementation will be only affordable for large projects when compared to the economic capacity of a city as a whole, especially in the developing world. The city as a single stakeholder unable to acquire or demand CIM in its management practices has to depend on the knowledge and practices of the private sector for its application on their projects. Nonetheless, the built environment industry has been historically slow on uptake of technological innovations. Therefore, the demand for CIM is likely to remain scarce due to the balance between the industry's innovation capacities and the city's multidisciplinary traditional practices. Moreover, there is a perception that there is potential resistance from professionals unfamiliar with the digital model scopes, which will likely influence the early adoption of CIM-generated products at all stages in a project or facility lifecycle. Thus, CIM will remain temporary and superficial in these cases, not entirely leveraging its potential.

6.1. Data Privacy and Security Concerns

The proposals to extend digital information modelling from buildings to cities in City Information Modelling (CIM) have greatly promoted the development of digital cities . The data opened out by various CityGML Conversion Tools and data providers in very high levels includes the full details of the building model, in which some sensitive information usually appear. The disclosure, sharing, and use of data in the process of a city information model (CIM) may lead to a leakage of sensitive information. The concern of the security and privacy of transferred CIM has arisen as these evaluations begin to be released .

When broadly establishing the digital city model, such kind of model can cover the online tenancy of home owner, electronic device usage, operating frequency of facilities in air quality monitoring stations, flow of a compartment or a zipcode, and other information that related with the personal privacy but universally ignored. The initially official CIM Model and CIMGBS project document have something to say about robustness test, which is a satisfactory thing, but almost nothing on privacy threat, which is not. At different phases of the CIM project and aids, there are a number of best practices for data protection laying down. For the public and other stakeholders involved in a CIM project, guidance on privacy issues should be produced as a requirement of the project's implementation. In part, this can take the form of standardized policy templates for data governance that set out minimum requirements for data owners or recipients in the way in which data is handled. Good practice guidelines for public communication, including transparent standards for public engagement and notification about the transfer and use of data, would also mean that data owners put public privacy awareness and transparency at the heart of their approach. A new data sharing and use philosophy of CIM would be promoted, built on trust and reassurance among stakeholders that any risk of misuse of sensitive data is minimized. It is noted that compliance with relevant data protection regulations is highlighted. In this context, this may represent the GDPR within European Union countries.

6.2. Technical Barriers to Adoption

City Information Modeling (CIM) could have a major impact on how the built environment is modeled, analyzed, visualized, and managed but as with the slow and partial diffusion of Building Information Models (BIM), there are many barriers to implementing CIM. One significant barrier is the complexity of existing software for modeling and analysis of the built environment, its effects on interfaces software environments. These barriers may not be easily overcome because they concern the design and protection of software products. Another barrier is the technical knowledge required to model, simulate, and analysis of the built environment using new tools, methods, and technologies. The high level of hardware and software required to perform this analysis is another barrier. Because city models will require data from many different fields there is also a need for a vast number of expensive analysis tools, some of them custom made. Another significant barrier is the difficulty in making new integrated modelling technologies interoperable with older, largely 2D GIS software (Xu et al., 2014). Proprietary formats and business models can prevent the sharing of information between applications or businesses. Open standards may vary in efficacy. Another barrier is that few organizations currently have staff educated or trained in the use of new integrated modelling technologies. Overall barriers represent a huge investment of capital, time, and staff resources. The reliance on legacy models, software systems, and businesses practices in applied disciplines may also be a barrier as new technologies may not fit well with older subsystems. For example in the infrastructure sector it may be difficult to model transport and water systems in the detailed way possible structures, also the long lifecycle of infrastructure systems may mean that legacy subsystems have a long life, the difficulties of diminishing funding, and overcoming lock in effects may be difficult to overcome. Potential mitigation strategies for overcoming these barriers should be based around phasing in the adoption of these technologies. In the early stages of adoption, only the simplest and most tested of technologies should be made use of. By refining design before ground is broken, a greater level of certainty can be developed in the plans, thereby limiting the cost of potential errors. Staff can be trained in these lower level technologies without the need for vast amounts of specialized equipment. Subsequent technologies must come to be open and widely accepted and efforts to fund and develop common systems must be supported (Anton Kivits & Furneaux, 2013). Moreover, transferring or upskilling of staff from better funded disciplines should be promoted. Administrative structures should be developed to streamline the collation, analysis and redistribution of data between all parties. Examples of present integration practices could provide insight to develop such structures and to highlight potential pitfalls. At the most advanced level of these problems there is the potential to field technologies in house, the development of integrated modelling divisions would foster more flexible methodologies and could better respond to clients need. As these newer technologies develop fewer obstacles to their application may be present. High resolution 3D scanners and printers may open up small operators capabilities to use the same detail in their work as larger ones. Finally urban and regional planning regulations are beginning to incorporate the use of 3D models, mandating the use of these new technologies for a broader base of potential industry actors. Although some of these regulations are initially based around crude modes for new developments it is likely they will also require the production of 3D maps of existing topology.

6.3. Cost Implications

The major cost implications of adopting CIM include technology costs (software, hardware, and data acquisition); costs of training staff and consultants; costs of maintenance and updating; and upgrading existing systems to be CIM-compliant. Financial constraints limit the feasibility of adopting CIM in many urban settings. Concerns are frequently voiced about the level of investment and the ongoing costs in relation to the perceived advantages of improved services and cost efficiencies. It is generally believed that the benefits brought by CIM have to offset the cost of its deployment and operation. Recent research shows that despite investment in technology and expectations of savings, the initial cost of implementing CIM may be high, and its advantages are difficult to quantify in real financial terms. Around half of the stakeholders involved in urban management and development are of the opinion that a city-wide model has an uncertain financial future. While some relatively small towns and cities in developed countries have or are acquiring 3D models, many large and middle-sized cities, as well as almost all cities in developing countries, are struggling to assemble the finances necessary for this. However, financial barriers are only part of the problem. Even where major 3D models have been developed, very little imaginative use has been made of them: they are employed mostly for public relations or very local development control (Xu et al., 2014). There is a clear indication that urban modelers are more interested in the practical use of the model for day-to-day urban management-planning tasks. The majority of property developers and professionals have one of the five most common views, each representing skepticism in a different way. They consider that the model is "expensive" or "a waste of money" because they are concerned about the initial financial investment for acquisition and deployment, and how the city decision makers afford this. The situation is aggravated by the fact that costs are immediate, while benefits can only be realized over the long term. There is fear that the politicians who are supposed to approve funding might be "impatient" and look for quicker and more tangible returns. This is a feasible concern surmising that decision cycles are short and politicians of a particular party may not be re-elected. On the other end, the modelers see the system as a "long-term investment". From this viewpoint they emphasize the operational costs rather than the high up-front investment. However, the current costs may be excessive, and the need for a redesign using the lessons learned is highlighted. They propose innovative funding through multidisciplinary teams and partnerships with the private sector, especially where agreement on data sharing and operational synergies exists. Finally, each group finds a place for user charges that will move from the current one-size-fits-all to a payment-by-service system. This includes charges based on generated income and size-mixed-use functions, as well as incentives for using environmentally-friendly materials (Goucher & Thurairajah, 2012).

7. Future Trends in CIM and Urban Planning

Looking ahead, there should be an understanding of changing technological opportunities that will become available, and the implications of these for City Information Modelling (CIM) and for how one approaches looking at the analysis, management and design of future cities in general. Potentially the most important technological development to influence CIM concerns the recent advances in the Internet of Things (IoT). Cities, buildings, and the infrastructures within them are becoming increasingly intertwined. With this interconnection comes a wealth of data on how people, goods and energy consume and then move through urban environments (Mine Thompson et al., 2016). In order to respond and best utilise these new digital opportunities, there must be advancement in big data and network analytics. These technologies permit the mining of patterns within massive, complex and connected datasets; understanding the implications of this technology for the development of CIM applications can help to predict the future smart city in general.

Alongside the data-centric applications of this growing digital infrastructure, the maturation of Artificial Intelligence (AI) and machine learning has the potential to greatly influence the urban decision-making processes. The industry is signalling a move away from the static rule-based systems used in transport, building technology and urban management, towards more dynamic learning algorithms. One direction that research in these fields and urban modelling overlaps is that of the agent-based simulation (ABS). Agents are distributed, autonomous and interacting entities; they can be combined into computational models of families, individuals, buildings, or infrastructures.

Given the complexity of the future digital cities, the design and management of the urban environment should be based on multidisciplinary collaboration with the public. The City Information Model (CIM) used for this should be adaptable, allowing the public to input diverse data relevant to them. The ultimate aim of such work is to encourage the development of synthetic environments that allow the wider public to engage and collaborate with city authorities and stakeholders in urban planning and policy decisions. It is widely recognised that future cities will be expected to be more sustainable and resilient. In terms of both sustainability and resilience, there are many current practices and city technology models which are sure to evolve and become more sophisticated, influencing the City Information Models of the future.

7.1. Emerging Technologies in Urban Modeling

Emerging technologies are shaping both urban life and the landscape of urban modeling, and these technologies can be embraced by urban modeling research and practices to promote urban innovations . Among the waves of emerging technologies, special attention is paid to those with the potential to innovate urban planning and management and to the modeling of cities or the representation of urban environments. With this focus, artificial intelligence, machine learning, and the Internet of Things are highlighted, as well as the large dividends that data analytics can provide for insights into the opportunities and challenges in urban development. Several innovative technologies in these areas are introduced, such as sustainable urban development indicators. Technologies that facilitate the analysis and representation of public spaces in cities in both the physical and social dimensions are covered for their affordances in understanding and modeling the use of public spaces.

The application of Building Information Modelling technology now expands to city infrastructure in which City Information Modelling is used for building. How to integrate BIM and CIM to facilitate urban construction becomes a new problem. This paper establishes a framework for the automatic transformation of BIM data to CIM data according to the standards of CIM as a solution. To obtain consistent model data, an automatic modeling method based on the extraction of a room pattern model in the form of data and then engenders other CIM data is used to achieve automatic transformation. The model is verified in a study case. Regarding the integration of new technologies into urban modeling, it is suggested that this should be approached with strategy rather than out of ad hoc reactions for pragmatism. In particular, the view advanced is to avoid replacing entire existing frameworks entirely but to judiciously combine and integrate existing systems and best-practice experiences with new technologies. It is argued that this method can not only avoid immediate implementation constraints but can also serve as fertile soil for new technologies by incorporating them organically into robust existing practices. Central to this notion is the principle of pragmatism in using what is at hand and fruitful, of creating what is missing, and of always adapting practices in anticipation of future challenges and opportunities.

7.2. The Role of AI and Machine Learning

With the rise of Building Information Modeling (BIM), hundreds of software applications have been developed worldwide to offer BIM modeling, analysis, and visualization of energy and cost performance. Paralleled with BIM, City Information Modeling (CIM) technology has been launched, which provides more functionality to handle both the Building Information Modeling data and the City GML data. Currently, CIM is used by many planners for enhanced 3D city analysis and generation. It is a brand new approach to 3D city management and has a broader application in the whole city field like intelligent transportation system and virtual reality (Xu et al., 2014). Future research of CIM should focus on more of the urban design optimization, GIS solutions and conversion issues.

Meanwhile, the role of CIM should be further extended to enhance the 3D pollution simulation, pedestrian/crowd simulation, light/shadow analysis, disaster simulation, 3D/4D/5D CAD spatial data sharing, intelligent urban design, green urban planning analysis, city delta management, and historical building simulation. Artificial Intelligence (AI) and machine learning technology have been applied in urban modeling and it can offer additional benefits to 3DCIM. As City Information Modeling (CIM) solutions evolve and expand, the advancement of CIM technological capabilities will provide more potential for the research in artificial intelligence and machine learning tools. Today's machine learning and artificial intelligence are changing approaches to solving data analysis and decision-making tasks. People consider too many problems related to daily life or work and find solutions inspired by the machine learning paradigm.

After decades of theoretical research and practical applications of machine learning and artificial intelligence, there is a growing outlook and interests focusing on the relationship between the stability improvement of the existing algorithms in the environment of big data and the development of new learning and reasoning algorithms. Always taking time to seek out insights from information is not something that can be accomplished without assistance. With the advent of the Big Data era in which we are currently immersed, a lot of information can pass us by (Wang et al., 2023). For today's urgent matters and emergency responses, such as emergencies in downtown areas, it is difficult to locate and evaluate risk points before the event. By using vector, raster, BIM, and other 2, 2.5 or 3D data for a specific city at specific points, researchers can semi-automatically search for hidden rules, model the transformation to other urban locations, and get results with geographic coordinates in other urban places and data. At such a moment, machine learning supported by AI would be very helpful, so ready-made solutions need to be integrated into the CIM program. As the driving forces for urban planning shift over time, technology is presented to answer about the trends.

7.3. Public Participation in CIM Processes

Public participation is one of the democracy's core principles and regarded as essential for community development. In the processes concerning City Information Modeling (CIM), public involvement appears in various forms. The benevolent one may help to make sense of the complex issues, mediate and conciliate different interest groups and increase the social acceptance and trust. Especially, in the formative urban planning stage, the engagement of civic society affects the fundamental decision-making processes. The clear plan and strategies to involve community and stakeholders is considered as one of the critical factors for a successful project. A common feature is to adopt an inclusive attitude in dealing with diversities and disparities. A method to present alternatives in a clear way and integrate participatory GIS (Geographical Information Systems) and visualization technique into consultation exercises is considered beneficial. This would help make people to understand legitimacies, trade-offs and options available by revealing the complexities and interconnectedness of urban systems and planning decisions, and by doing so would foster a transparency culture (Xu et al., 2014). In the case studies of CIM applications in land use planning and urban redevelopment, interactive consultations ex-ante social impact have been undertaken through a number of public dialogue programs. Though views and demands from different sides can be better understood through direct communications, the variety of stakeholders tends to render contradictory advice. It is extremely challenging to take rational or effective decisions following the often opposed views and complex interactions of stakeholders. Therefore, systematic measurements are necessary in order to have a holistic understanding of urban problems. Moreover, continuous feedback is crucial to see how the opinions or the preferences have been incorporated, and to keep generating backing to planned initiatives. The development and maintenance of CIM systems should therefore include public participation as a core element.

8. Conclusion

Throughout the last hundred years or so, models have been increasingly and effectively used in architecture, construction, and urban design as an efficient way to visualize, analyze, and manage buildings and the urban environment. A Building Information Model (BIM) is a digital representation of physical and functional characteristics of a place, but goes beyond traditional 3D geometrical and elevation models by adding operational information to the model (Xu et al., 2014). More precisely, BIM is a relational database of a building's most critical information, which enables modeling its geometry and properties on various aspects of the building: spatial, structural, installations, conceptual, temporal, etc. Therefore, the BIM model becomes an accurate, precise, and up-to-date representation of the real building that was built, is being built, or will be built. The BIM model is used during the whole lifecycle of a building: from the very first phase of conception and design, through construction, operation and maintenance, to refurbishment or eventual demolition. This information stored in the BIM database is very precious to building operators. By using this information, the builders can change the building back to what it used to be good and fast. In each phase, the operators need different kinds of information and the information should be timely updated and maintained. Since the same goes practically and theoretically for cities as it goes for buildings, the concept of City Information Model (CIM) arises. The idea is smartly following the leap of building information modeling through the phases of the building lifecycle and the increasing prestige and successful operation of GIS technology in the case of the urban environment. Therefore, the idea of CIM is at first presented and hinted in the discussion primarily through the point of view of urban planners. The development of transportation networks, including improvements and extensions of existing networks to newly planned cities or to restructured or upgraded existing ones is the key challenge for managing the issues associated with such rapid urbanization.

A city has a complex model with modals up to social modals. Those urban models are not up-to-date because of the high cost associated to the collection and storage of modals related information. A CIM will permit to combine modals from different sources in a city map with up-to-date information. The integration of this city map with the managers' data modals is done in the GIS. The new modals related to the evaluation of a large scale transportation project are stored in the GIS (Mine Thompson et al., 2016). The proposal presented in this work is part of the EPIC project that aims to develop the CIM. Hence the impacts of transportation projects can be evaluated in a more automated and comprehensive way. It is also noted that passenger demand consolidation and elasticity computation will constitute milestones in the bridge between the models. At present, the management of information in cities is carried out by several stakeholders, engaging legal, economic, and social procedures. Enforcement of city laws requires approval of specific types of permits, such as building and business permits, street trading, etc. This compliance is mandatory for both public and private stakeholders since numerous city income receivers are managed. Building laws are of the most complex, since they separate building and construction into several zones. A further layer of complexity is added through different construction techniques and raw materials allowed for each zone/type. Engaging field of the new SIM tool is to substantially enhance this process for all city stakeholders. Information can be visualized in CIM, with data entry forms provided for insertion of the specifics of any legal procedure to be initiated. AStreet view of the area of interest can give a more complete understanding beforehand, and enforcement can analyze buildings' 3D facades against existing ones. Each time a warning is to be sent, the respective CIM data will be automatically completed, and a 3D fix building and 4D transportation will also be attached in the legal file. Notification in case of emergency will be achieved through the SIM network. In opposite of the legal procedures involving more than one department of the government or coordination with stake holders, notification will be bound by agencies that are set will have to produce the final advice.

References:

1. Tah, J. H. M., Oti, A. H., & Abanda, F. H. (2017). A state-of-the-art review of built environment information modelling (BeIM).
2. Xu, X., Ding, L., Luo, H., & Ma, L. (2014). From building information modeling to city information modeling.
3. Barbato, D., Pristeri, G., & De Marchi, M. (2018). GIS-BIM Interoperability for Regeneration of Transurban Areas.
4. Ellul, C., Stoter, J., Harrie, L., Shariat, M., Behan, A., & Pla, M. (2018). INVESTIGATING THE STATE OF PLAY OF GEOBIM ACROSS EUROPE.
5. Mine Thompson, E., Greenhalgh, P., Muldoon-Smith, K., Charlton, J., & Dolník, M. (2016). Planners in the Future City: Using City Information Modelling to Support Planners as Market Actors.
6. Faltejsek, M. (2019). Simulations as Part of the BIM Concept in Urban Management.
7. Anton Kivits, R. & Furneaux, C. (2013). BIM: Enabling Sustainability and Asset Management through Knowledge Management.
8. Goucher, D. & Thurairajah, N. (2012). Usability and Impact of BIM on Early Estimation Practices: Cost Consultant's Perspective.

9. Wang, D., Lu, C. T., & Fu, Y. (2023). Towards Automated Urban Planning: When Generative and ChatGPT-like AI Meets Urban Planning.