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Technical Systems Design Using BIM Methods

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This thesis is dedicated to my mother AND MY SISTERS.

For their boundless love, support and encouragement

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Throughout the process of writing this dissertation, I had a lot of help and support.

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Thank you all my friends, colleagues, and the people I have met over the years.

1 Contents

2 List of Acronyms and File formats

AEC “Architecture engineering and Construction”

AIA “American Institute of Architects”

BEP “BIM Execution Plan”

BIM “Building Information Modeling, Model or Management”

BSI “British Standard Institute”

CAD “Computer-Aided Design, Drawing, Drafting”

CDE “Common Data Environment”

CSC “Construction Specification Canada”

CSI “Construction Specification Institute”

FM “Facility Management”

IBIM Integrated Building Information Modeling

IFC Industry Foundation Classes

ISO International Organization for Standardization

LOD Level of Detail / Development

PM Project Management

WBS Work Breakdown Structure

.dwg Autodesk® Autocad® and Advance Steel® drawing format

.html Hypertext markup language

.mpp Microsoft Project file

.nwc Autodesk® Navisworks® cache file

3 Table of Figures

4 Abstract

Building Information Modelling (BIM) has already a recognized phenomenon on a global scale, to deal with project complication and improvement even in the heating, ventilation and air conditioning sector (HVAC). Although adoption is still unbalanced and varies between different construction sectors.

To reduce disorientation above the ultimate goal in this thesis is to develop and provide BIM technology in the practical applications to enhance the design and construction process in HVAC system including "4D BIM," and "5D BIM" which link the tasks in a project's construction schedule time and cost management to its 3D model through the Navisworks and PriMus-IFC software respectively.

Among the collaboration with the Prodim consulting engineering company it became achievable to complete the thesis Appling to the actual cases which were the UNIPOLSAI complex tower in Turin Piedmont Region and Kuadra school located in Cuneo in Piedmont Region.

By investigating all the data and the documents provided through the process in the both case of studies thanks to the BIM systems we were able to the early detection and elimination of problems such as interference through the design and producing benefits such as accelerate the construction process, reducing the number of resources for both schedules (4D) and costs (5D) respectively.

Although it would be ideal if this could be generated automatically, it is currently not feasible and needs a lot of manual work. The capacity to fully profit from BIM is still hampered by the fact that the project participants' levels of BIM maturity and skill still vary widely.

Figure 1. Building Information Modelling source: pbctoday.co.uk

5 Introduction of BIM

Building information modelling (BIM) is one of the advancements in construction technology that the digital age has brought us. BIM is not a new concept instead it has been with us for many years now. The development in technology has enabled the construction industry to plan, design, construct and manage more complex and large-scale projects every year more and more professionals on architecture, architectural technology building, surveying quantity, surveying construction management and property development and planning are implementing BIM. The benefits of using BIM include enhancing project efficiency, enhancing stakeholder collaboration, and developing a central model that houses all project data or merely some of it. [1]

5.1 Definition of BIM

BIM is development, not transformation. It was advanced over decades by various scholars from all over the world who operated together with software designer. The first BIM model shown on pcs was 1984. For the first time in 1986, Robert ash presented the phrase building modelling. Building performance data appeared in early BIM applications in 1993. The golden years of BIM development were from the late 1990s to the early 2000s. Collaboration on central models performs on BIM presentations in 2004. From that point on, technological development developed significantly, and in 2008, further innovative technologies, including parametric modelling and laser scanning, were integrated into BIM systems. After 2015 different government made amendments to the existing construction regulations to improve the incorporation of the BIM process for example in 2016 use of BIM processes in funded projects became mandatory in UK. In 2020 Germany complete it essential for transportation plans to usage the BIM method. While there is a different definition of BIM it is a process that improves collaboration between different stakeholders throughout the building's lifecycle. BIM is a process of operating collectively to increase the productivity of construction projects and the most important element of a BIM procedure is a BIM model that contains all information of construction. [2]

A BIM model includes a detailed 3D model with all architectural and structural elements mechanical and electrical systems, spaces, a details schedule, and all sorts of documentation. It can quickly calculate things like cost estimates, material amounts, and energy efficiency. It is not true that BIM is only useful for large and complex projects because implementing BIM is highly beneficial for different types of projects with various functions and scales. Also, scanning to BIM for real-time surveys and incorporation of sit features create a huge potential to design and construct spaces that are perfectly integrated with various site-specific conditions. Implementing BIM will also increase project precision and accuracy, with fewer errors and mistakes. It will also improve the coordination between different disciplines involved in the project which would eventually result in minimizing the time and cost of the project. Using BIM, we can have planned overlaps space in different stages of the project which results in reducing the project's jects time and cost. [2]

5.2 BIM'S Development

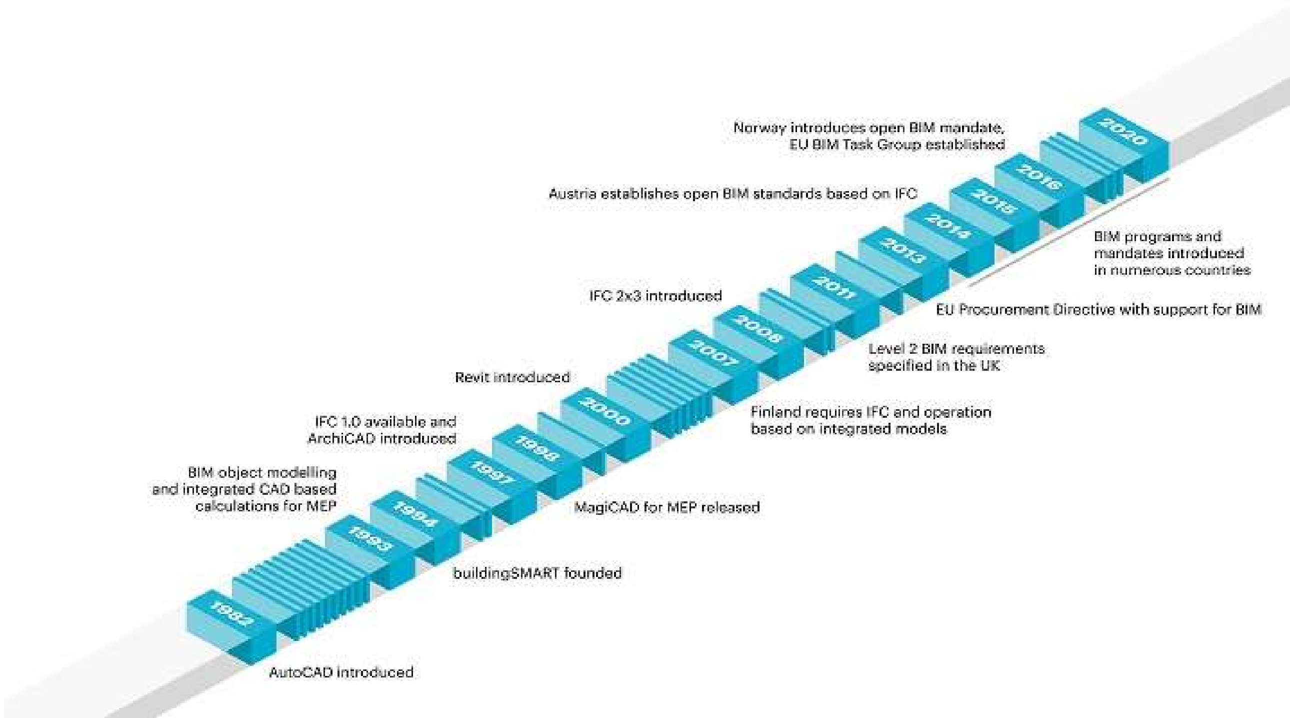


Figure 2. Development OF BIM. Source: Magicad

6 History of BIM

6.1 Early BIM Beginnings

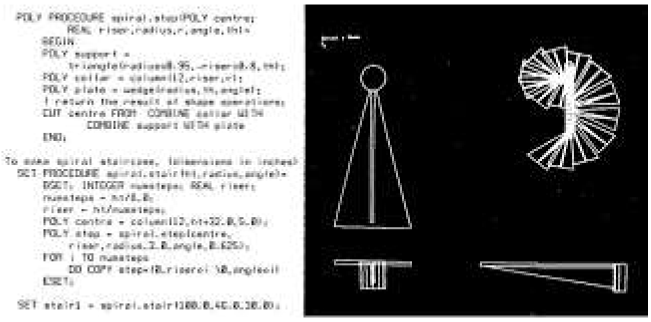


Figure 3. A Brief History of BIM. Source: Archdaily

To recognize the history of BIM and BIM systems, it is essential to go back to the dawn of computing and explore the conceptual foundations. Computer-Aided Design and Computer Aided Manufacturing (later Machining) evolved as two separate technologies, he said, almost simultaneously until the 1960s. At the time, no one expected that both CAM and CAD would eventually intertwine and become a powerful force in the industry (American Machinist, 1999). In 1957, his Pronto, the first commercial computer-aided manufacturing (CAM) software, was developed by his Dr. Patrick J. Hanratty. It was a numerically controlled machining technique that later evolved into computer-aided manufacturing. He soon dabbled in computer-generated graphics, and in 1961 interactive he developed DAC (Automated Design by Computer), his first CAM/CAD system to use graphics, Used for complex mold tools at General Motors. After some setbacks, mostly due to unpopular programming languages, Hanratty said: And it should always be open to communicate with other systems, even competitors.” [3]

6.2 Creating a Dream Model

Figure 4. Ivan Sutherland's Intent In Sketchpad Presentation. Source: Scan2cad

Ivan Sutherland created "Sketchpad," the first computer-aided design (CAD) program with a graphical user interface, at the MIT Lincoln Labs in 1963. Overall, it paved the way for human-computer interaction and represented a significant advancement in the field of computer graphics (Sutherland, 2003).

In terms of construction technology, Sketchpad was replaced by programs for solid modelling; as computational representation of geometry advanced, it became possible to display and store shape data. Constructive solid geometry (CSG) and boundary representation were the two main techniques that emerged from this in the 1970s and 1980s (brep). This offered the problem of controlling the computer in a straightforward manner throughout the entire design process, which required an intuitive relationship to the design medium [4].

6.3 Creation of The Database

Building Description System was the name of a prototype that Charles Eastman described in a 1975 study (BDS). With a "single integrated database for visual and quantitative analytics," it examined the concepts of parametric design and high-quality computational 3D representations. In essence, Eastman's work outlined BIM as it is today.

Information may be obtained categorically by qualities (including material and supplier) using the program that Eastman built. It also used a graphical user interface, orthographic views, and perspective views. The BDS detailed discrete library pieces that could be fetched and added to a model, making it one of the first initiatives in BIM history to do so successfully (Bergin, 2011).

Eastman came to the conclusion that BDS would increase drafting and analysis efficiency and reduce design costs by more than 50%. The BDS experiment helped to pinpoint the most significant issues with architectural design over the ensuing fifty years. The majority of the traits of the current BIM platform were present in Charles Eastman's GLIDE (Graphical Language for Interactive Design), which was developed in the CMU Lab in 1977.

6.4 Moving Toward Virtual Construction

While improvements were quickly occurring in the United States and England, a computational and programming prodigy in communist Hungary was breaking the law by smuggling Apple computers behind the Iron Curtain to create. Software that, in the future, would alter the course of history and create the modern-day BIM industry and the BIM idea (Arnold, 2002). In order to smuggle Apple computers, Gábor Bojár had to pawn his wife's jewellery in 1982 when he began developing ArchiCAD. In 1984, Bojár released Graphisoft's Radar CH for the Apple Lisa OS, utilizing similar technology to the BDS. [3]

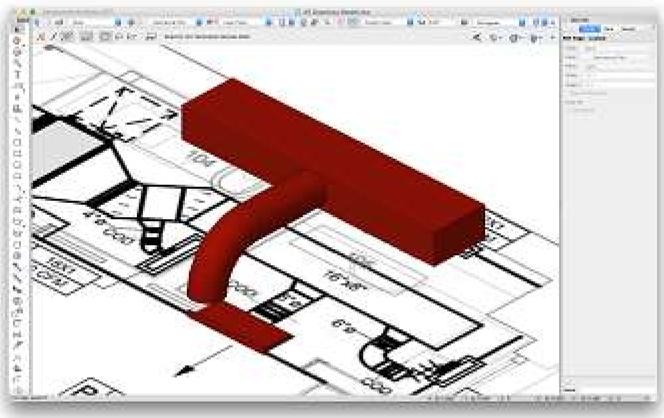


Figure 5. Vectorworks Architect 2017. Source: Vectorworks.Net

Later, this was released in 1987 as ArchiCAD, becoming the first BIM program accessible through a personal computer (Bergin, 2011). In 1987, Tekla completed the combined graphics and relational database for their early BIM system, precisely 2000 kilometres up north from where ArchiCAD was being created using the virtual building concept. Let's go back to 1985 when Diehl Graphsoft was creating Vectorworks, one of the earliest CAD programs, one of the first 3D modelling applications, and the first cross-platform CAD tool. One of the first software programs that offer BIM features was Vectorworks. Parametric Technology Corporation (PTC) was established at the same time (in 1985), and Pro/ENGINEER, which is regarded as the first commercially available parametric modelling design software in BIM history, was published by PTC in 1988. Irwin Jungreis and Leonid Raiz left PTC to start their own software business, Charles River. [3]

The team aimed to create a Pro/ENGINEER architectural version that could manage more intricate projects than ArchiCAD. By the year 2000, they developed a program called Revit, a made-up name that is meant to imply speed and revision (a reader remark claimed it was a portmanteau of "Revise it!"). By utilizing a parametric change engine made feasible by object-oriented programming and building a platform that allowed for the addition of time attributes, Revit revolutionized BIM. [3]

The creation of the Building Design Advisor at Lawrence Berkeley National Lab in 1993 is one of the significant events in the history of BIM. Software was used to run simulations and make recommendations for fixes based on a model. In Australia, Mapsoft was established in 1994 and started developing the cost-effective CAD software for surveys. MiniCAD, the first survey CAD program to run on the DOS-based HP100LX handheld computer, was made possible as a result. It is still utilized for Windows, Palm, and other vintage portable PCs today. [3]

7 The Development of BIM Terminology

In a 1986 paper that was published, Robert Aish was the first to describe the usage of the expression "Building Modelling." He argued in favour of what is now known as BIM and the technology needed to achieve it in this article. A few years later, in a study by G.A. Van Nederveen and F. Tolman published in the December 1992 issue of Automation in Construction, the phrase "building information model" had its first formal appearance. [5]

Figure 6. BIM Terminology. Source: Stock adobe

8 Bring up a Culture of Cooperation

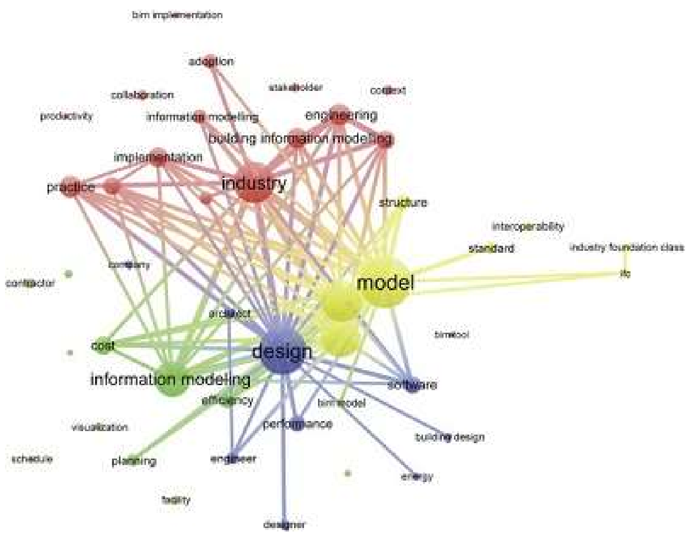


Figure 7. Collaboration in BIM. Source: Science Direct

Modern engineering, building, and architecture techniques have been trending toward teamwork. In the last decade, engineering system files have related to architectural files. The wider industry has been impacted by this culture of collaboration, which has been gradually shifting away from bid contracts and toward an integrated project delivery system where everyone works on a shared set of BIM models.

The International Foundation Class (IFC) file format, which essentially makes a file interoperable with various BIM tools, was created in 1995 to enable data to flow between platforms. The first Teamwork solution based on file interchange was made available by ArchiCAD in 1997. This transformed teamwork and made it possible for several architects to work on a building model at once.

Later updates to Teamwork enabled remote access to the same project through the Internet as well as more extensive project collaboration and coordination. In Japan in 1999, Onuma developed a database-driven BIM planning system that opened the way for later seamless cross-platform integration of BIM software and parametric technologies. This allowed virtual teams to collaborate on BIM via the Internet.

JetStream, a 3D design review program that featured a suite of tools for 3D CAD navigation, collaboration, and coordination, was created and commercialized by Navisworks in 2001. In essence, JetStream coordinated data in several file formats, enabling construction simulation and issue identification. It was made possible for larger teams of architects and engineers to work together in one integrated model software when Revit published its upgrade, Revit 6, in 2004. [5]

Autodesk purchased Revit in 2002, Navisworks in 2007, and other "smaller" BIM systems as it competed to dominate the BIM market. Autodesk created Formit at the end of 2012. A BIM model can be created on a mobile device using the Formit application. [5]

9 Modern BIM Techniques

Figure 8. design and construction with BIM. Source: Blueprojects

At this point are a few BIM participants who deserve to be mentioned. Despite having small market shares, they have had a significant impact on the design industry. Generative Components (GC), a BIM platform from Bentley Systems that focuses on parametric flexibility and sculpting geometry that supports NURBS (non-uniform rational B-spline) surfaces, was created in 2003. [6]

A tool comparable to GC called Digital Project was made available in 2006 by Gehry Technologies. Architectural designs underwent a change thanks to both the Digital Project and GC. In a sense, these two platforms are revolutionary because they may create architectural forms that are very complicated and contentious, opening the way for parametricism. In 2008, Patrick Schumacher popularized the term "parametricism" and the practice of creating parametric architectural systems. He emphasized the value of understanding the contemporary BIM platforms (DP and GC) in the Parametricist Manifesto to compete in the modern architecture landscape. He is cited as saying: [6]

The recent step of improvement within parametricism owes as much to the continual development of the supportive computational scheme tools as it is because the designer has understood the specific formal and organizational potentials that are supplied. Only through complex parametric methods is parametricism possible. Scripting (in Mel-script or Rhino-script) and parametric modelling (using tools like GC or DP) are computationally sophisticated design methods that are finally becoming a widespread reality. Without accepting these approaches, one cannot compete in the modern avant-garde scene today. [6]

The integration of technology is gently causing a generational drift with all the parameticist viewpoints and the ideals of the "elder tradesmen." For instance, a highly skilled architect who is unfamiliar with the program interface and concepts can do more work than an "entry-level" designer who is familiar with the fundamental instructions of a software program. [6]

Given that all these abilities and methods can be learned, architectural colleges and even software developers offer specialized instruction for particular programs. Worker "outdatedness" is fiction because all these new technological integrations are attainable. [6]

10 The Direction of BIM

Although BIM has been around for at least 40 years, the design, engineering, and construction industry are only now beginning to realize its full potential. With "sustainable design methods, human-computer interaction, augmented reality, cloud computing, and generative design," virtual design and building are gradually being integrated (Bergin, 2011). These themes are rapidly and continuously influencing how BIM is developing. Being interested and witnessing the development of construction technology is in fact a thrilling moment. (Bergin, 2011).

11 Problems before BIM Implementation.

Let's examine some of the numerous challenges the construction sector was dealing with prior to the adoption of BIM. [7]

- Incompatibility: There are many issues with file sharing and various file formats.
- Extensive use of paper.

  The main result of our careless use of paper is deforestation. In safeguarding ecologically significant forests and restricting commercial access, conservation organizations have made impressive progress. For humanity, this is a huge step forward! Just consider how much time it will take a tree to reach its maximum size. We are only now becoming aware of the unnecessary exploitation of our trees, which emit oxygen and shield the world from further global warming.
- Email overflow as more talks among many stakeholders is needed.

  These days, email overload is a regular issue. It might be challenging to keep up with the flow and prioritize the communications when there are so many pouring in. Frequent email checking can disrupt your workday and rob you of time that could be spent on more significant things.

- Minimal data security

  Data security is the process of protecting corporate information and preventing data loss due to unauthorized access. This entails safeguarding your data from attacks that can alter or damage it, as well as assaults that can encrypt or destroy it, like ransomware. Data security ensures that any company personnel who require access to the data can get it. Model and data ownership are unclear.

- limited transparency in the exchange of information
- Loss of revision documents

  A planned versioning strategy is document version control. Versioning was a deliberate choice when all enterprise content management (ECM) systems were run locally. So that everyone knew which versions were retained, content teams had to reconcile revision tracking with storage constraints and organizational needs.

- little project documentation

Finally, there was no single model that contained all project data Min. Utilizing a single system of digital models has the benefit of improving the synchronization of numerous documents created by various specialists involved in a project.

The collaborative process of planning, constructing, and managing a building or infrastructure utilizing long-range digital models is known as BIM. [7]

12 Potential Advantages of BIM

Within the AEC sector, the potential economic benefits and increased productivity associated with the successful application of BIM are widely recognized and increasingly becoming clearer (Bernstein and Pittman 2005). The advantages and potential benefits of this new technology in comparison to conventional 2D CAD have been the subject of several research. For instance, "BIM is definitely feasible and has several practical advantages over CAD." - Batcheler and Howell (2005) As the adoption of BIM grows, project team communication should rise, which will enhance profitability, cut costs, improve time management, and strengthen client/customer relationships. - Azhar and co. (2008) " Creating information models enhances software exchange by reducing data input and transfer errors and accelerating analysis cycle times." Fisher and Kunz (2006) BIM can offer significant advantages, but doing so necessitates a change from conventional working practices. Arayici and others (2009).

Figure 9. Advantages of BIM. Source: Constructiontuts

Many people have suggested using BIM to boost the historically low productivity of the AEC sector. Studies, according to Kiviniemi (2013), demonstrate that the AEC industry's productivity has developed far more slowly than that of other production industries; some even show that its productivity has fallen over the past 40 years. This development results from a lack of redundancy and inefficient information flow. BIM is a method of tackling these problems by enhancing the management of information in construction projects and fostering greater collaboration across the incredibly fragmented AEC-industry. BIM is a tool to facilitate this better productivity, not the end in itself. (Eastman et al. 2011; Kiviniemi 2013) BIM has been promoted as a technique to boost performance in the facilities management phase of the project as well as throughout the project's actual execution. The three benefits of using this new technology, according to Ding et al. (2009), are benchmarking, benchmarking, and digitalization. The facilities management system will be strengthened and made more sustainable if the model can accommodate these three factors. The facilities management staff and the company as a whole will be more productive and efficient, and the owner's return on investment will be higher. 2009 (Ding et al.) The majority of facilities management systems do have access to all of the data. These systems also struggle to integrate and reuse information that could be obtained from the facility and its associated operations. By acting as an information storage platform throughout the duration of the project, BIM can complement the facilities management system by replacing the conventional "as built" drawings with an "as commissioned" or "as maintained" model. 2009 (Ding et al.)

13 Top 7 Benefits of BIM

The usage of BIM and software can improve a building project at every stage. Below, I have outlined a few of the main benefits of BIM for building. [8]

Figure 10. Benefits of BIM. Source: BIMspot

13.1 Increased Productivity

One of the main benefits of BIM is that construction projects run more effectively and with a shorter life cycle. It becomes simpler and quicker to handle and execute every component of the planning and pre-construction processes.

With BIM software, architects can produce designs more quickly, while estimators may use BIM models to provide more precise estimates.

Furthermore, BIM designs provide much improved cooperation and communication among diverse project groups. It ensures that everyone is always working with the most recent model because it enables different experts to view BIM schemes whenever they need to. By organising this, we be able to reduce errors and change carried on by using inaccurate or insufficient information.

13.2 Reduction on Expenses and Waste

By utilizing the resources offered by BIM software, contractors and designers can streamline their processes prior to the start of construction. Significant cost reductions and waste reductions may result from this.

BIM speeds the construction process, aids in minimizing human mistakes that may happen during construction, and helps contractors choose better materials. BIM can contribution suppliers in lowering the quantity of lost supplies by strengthening the planning stages. Consequently, it can lead to lower costs.

13.3 Better Cost Predictions

Working with a thorough model helps estimators to produce results that are significantly more accurate. A 3D model gives you a much more understanding plan to work off than a 2D blueprint. As a consequence, cost estimations based on models are more specific and accurate. Additionally, it speeds up the estimation process by making information and tools more accessible.

Beyond cost projections, BIM can optimize. BIM models provide a more comprehensive model to work from, which also makes quantity take-offs easier.

13.4 A Clearer Understanding of the Project

BIM designs provide a more accurate 3D investigation of the project's final result. This translates into a greater understanding of the result. Contractors and the client may benefit from this in order to gain a better understanding of the built asset. This not only helps in your considerate of the structure but also helps to prevent needless revise. A realistic 3D model of the project can help planners determine what will work and what has to be changed.

This enables contractors to adjust before they become a problem during the pre-construction stage. Rework avoidance can save a lot of time and money.

13.5 Cooperation and Communication

BIM is a strategy that encourages teamwork. Everyone participating in the project may effortlessly cooperate and communicate thanks to cloud-based BIM tools. They have 24/7 access to the most recent models and all the information they want. This lessens the need for pointless meetings and delays in workflow.

All planning stakeholders can work on the project's whole scope at any time. Models, estimates, and design notes are all produced and kept in one location.

As a result, architects may modify designs right away, and even when they're not on the job site, contractors can adjust the model. A project runs more smoothly and effectively when communication and collaboration are improved.

13.6 Less Risk and Waste

Building with BIM is safer and less dangerous. This strategy fosters closer contractor collaboration. It can thereby lower tender risk premiums. This enables a better overall view of the project prior to the commencement of construction.

This leads to improved site safety, less material waste, fewer misunderstandings, and so forth. Additionally, there is no chance of contractors using obsolete data.

Companies can reduce insurance costs and the likelihood of claims by using BIM technology and practices. BIM is therefore very helpful for reducing costs and managing hazards.

13.7 Improved Final Results

The improvement of the planning and building processes is the main goal of BIM adoption. This usually yields a build and final product of superior quality.

Contractors can perform higher quality work with better planning and more precise insights. The emphasis on the building's look is increased because architects can visualize the structure early. BIM generates constructed assets of a higher caliber as a result. [8]

14 Dimension 1D, 2D, 3D, 4D, 5D, 6D, 7D.

BIM is a digital representation of the structural and operational attributes of the building system, as has been stated numerous times during the discussion. Depending on its intended use, it may serve as a tool for exchanging dynamic information and knowledge about the building in order to support operational and decision-making activities that take place throughout the life cycle of the building element. The right to give an exhaustively informative digital representation of data for the purposes that are intended for the models, along with collaboration with those who have decision-making authority, is a prerogative. Modelling and content informational are object-based or based on items of a particular "kind" that are grouped into "families," as was already indicated. When discussing BIM from a form perspective, we discuss the technique for a number of different tasks, although it is frequently focused on the model object. This definition would be more limited than ever because, in the first place, the application of the BIM methodology could involve the creation of multiple models, negating the meaning generally accepted in the second place because it involves a whole host of applied processes to create, manage, derive, and inform stakeholders at various levels, at various times, and with various goals in order to ensure quality and efficiency throughout the entire life cycle of the product. Since digital modelling is often associated with three-dimensional representation, only a portion of the data in the templates is actually represented by this. Due to this specific feature, the "BIM dimensions" were created as an expansion of the geometric dimension. If the purpose of the models calls for it, the information they provide can therefore be used to define new utilities. The tenth dimension that can be achieved by the content information of digital models has currently been defined in the literature up to this point. ND modelling is a fascinating aspect of building information modelling. [9]

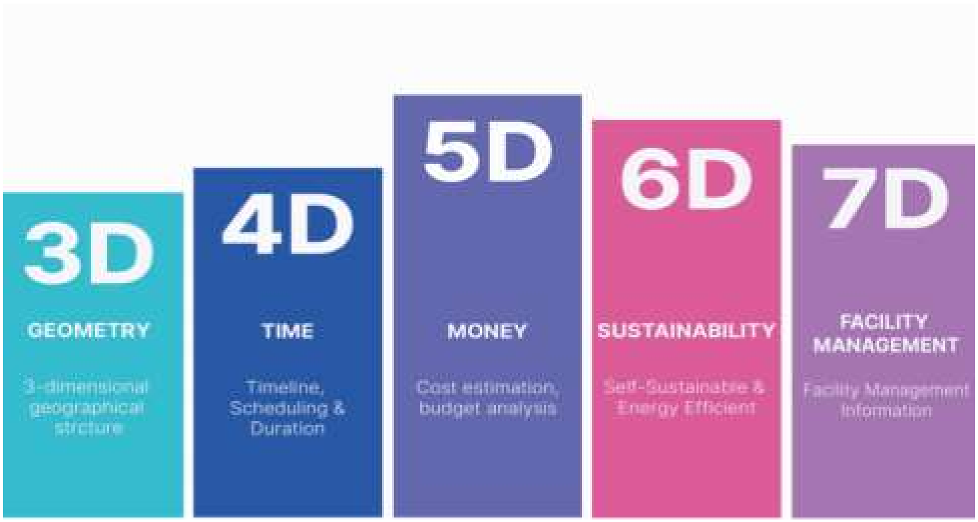


Figure 11. Dimension of 7D BIM. Source: Silicon engineering

The concepts of 2D drawing and 3D modelling are well known to all of us. Let's see how BIM has expanded the scope of our projects by utilizing its many features. Building models are no longer primarily associated with 3D technology. New chapters in the built environment sector's history have been made possible by the addition of new dimensions of time, cost, building performance, facilities management, and safety.

14.1 1D BIM

1dimension of BIM refers to strategies, estimation, and planning in projects. All the study on existing conditions, regulation, and diverse components of site analysis are considered in 1D BIM.

14.2 2D BIM

2 dimension BIM incorporates the production of 2D drawings, 2D views including plants, sections, elevations, and project documentation. 2D dimension is the earliest form of construction model. It constitutes a simple X-axis and Y-axis. These models are generally made by hand using manual processes or using CAD drawings. More advanced modelling tools now allow parameters, constraints, and concepts to be attached to the 2D model. However, most in the industry would not consider 2D geometry models as BIM. [9]

14.2.1 Example 2D for HVAC Systems

Being a single point of reference for information and operational operations, BIM has numerous dimensions. In this project, the second dimension of the tool allows us to estimate the heat load, size ducts and pipes, and design ducts and pipes. The building envelope properties, such as the walls, floor, ceiling, slab, type of building typology, location of the building, activity in the building, lighting load, equipment load, number of people, etc., must be supplied in order to carry out heat load calculations. By specifying the location of the building, it automatically calculates the dry bulb temperature, wet bulb temperature, humidity, etc.; these are essentially ASHRAE standards. [10]

The BIM model of the planned building used to determine the heating and cooling loads is shown in Fig. 12. The results of the BIM Model's calculations using the provided building design specifications are shown in Fig. 13. [10]

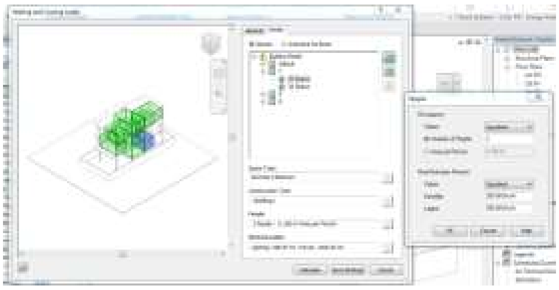
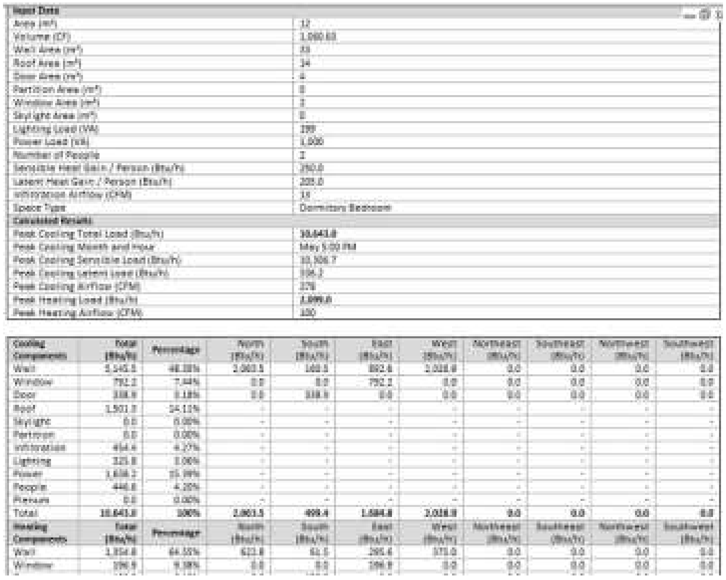


Figure 12. Heating and Cooling Load. Source: Conservesolution



Input Data	
Area (m²)	12
Volume (CF)	1,060.63
Wall Area (m²)	33
Roof Area (m²)	14
Door Area (m²)	4
Partition Area (m²)	0
Window Area (m²)	2
Skylight Area (m²)	0
Lighting Load (VA)	199
Power Load (VA)	1,000
Number of People	2
Sensible Heat Gain / Person (Btu/h)	250.0
Latent Heat Gain / Person (Btu/h)	205.0
Infiltration Airflow (CFM)	18
Space Type	Dormitory Bedroom
Calculated Results	
Peak Cooling Total Load (Btu/h)	**10,643.8**
Peak Cooling Month and Hour	May 5:00 PM
Peak Cooling Sensible Load (Btu/h)	10,306.7
Peak Cooling Latent Load (Btu/h)	336.2
Peak Cooling Airflow (CFM)	276
Peak Heating Load (Btu/h)	**2,099.0**
Peak Heating Airflow (CFM)	100

Cooling Components	Total (Btu/h)	Percentage	North (Btu/h)	South (Btu/h)	East (Btu/h)	West (Btu/h)	Northeast (Btu/h)	Southeast (Btu/h)	Northwest (Btu/h)	Southwest (Btu/h)
Wall	5,145.5	48.35%	2,063.5	163.5	892.6	2,028.8	0.0	0.0	0.0	0.0
Window	792.2	7.44%	0.0	0.0	792.2	0.0	0.0	0.0	0.0	0.0
Door	338.9	3.18%	0.0	338.9	0.0	0.0	0.0	0.0	0.0	0.0
Roof	1,501.3	14.11%	-	-	-	-	-	-	-	-
Skylight	0.0	0.00%	-	-	-	-	-	-	-	-
Partition	0.0	0.00%	-	-	-	-	-	-	-	-
Infiltration	454.4	4.27%	-	-	-	-	-	-	-	-
Lighting	325.8	3.06%	-	-	-	-	-	-	-	-
Power	1,638.2	15.39%	-	-	-	-	-	-	-	-
People	446.8	4.20%	-	-	-	-	-	-	-	-
Plenum	0.0	0.00%	-	-	-	-	-	-	-	-
Total	**10,643.8**	**100%**	**2,063.5**	**499.4**	**1,684.8**	**2,028.8**	**0.0**	**0.0**	**0.0**	**0.0**
Heating Components	**Total (Btu/h)**	**Percentage**	**North (Btu/h)**	**South (Btu/h)**	**East (Btu/h)**	**West (Btu/h)**	**Northeast (Btu/h)**	**Southeast (Btu/h)**	**Northwest (Btu/h)**	**Southwest (Btu/h)**
Wall	1,354.8	64.55%	622.8	61.5	295.6	375.0	0.0	0.0	0.0	0.0
Window	196.9	9.38%	0.0	0.0	196.9	0.0	0.0	0.0	0.0	0.0

Figure 13. Inputs and results of Heating and Cooling Loads. Source: Conservesolution

The desired ducting is designed using the necessary heating and cooling loads. Normally, the sizing of the duct in various locations to provide required conditioning is rather a complicated task, but BIM gives us the duct sizing according to the calculated CFM and FPM merely by entering the value of FPM, as illustrated in fig. 13. It provides the size of the branch duct and automatically calculates frictional losses in the duct and variable FPM in the branch duct. [10]

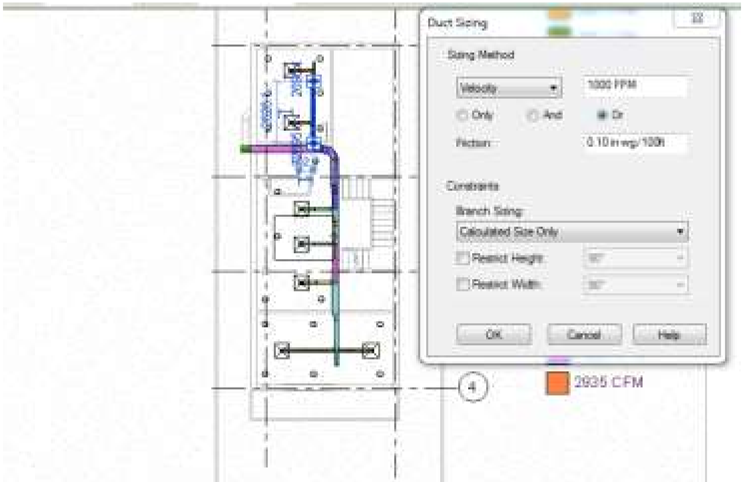


Figure 14. Duct Sizing. Source: Conservesolution

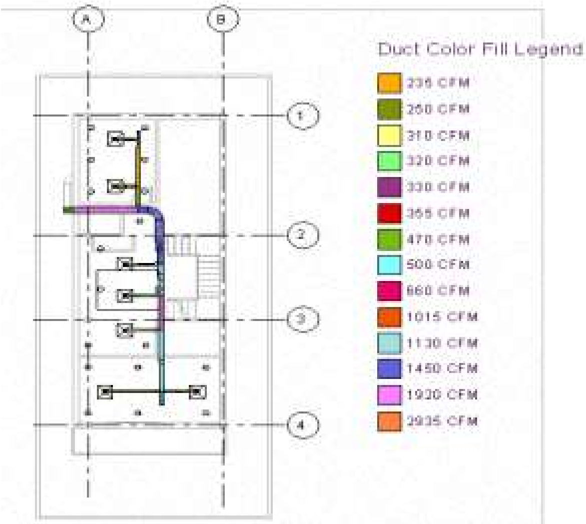


Figure 15. Duct Size Color Coding. Source: Conservesolution

14.3 3D BIM

Building 3D models, renderings, and walkthroughs are all part of 3D BIM. In addition, it involves creating 3D models using point clouds obtained via laser scanners. Another feature of 3d BIM is the integration of mechanical, electrical, and plumbing data with the 3D architectural models. Additionally, it allows for the detection of conflicts and interference studies between several fields. We now have new possibilities thanks to 3D modelling and BIM software. It works in coordination with other disciplines and is quicker and more accurate. The BIM tool synchronizes the change in all other views when we adjust a structure or geometry in a view like a plan, section, or elevation. Using 3D BIM, we can design conceptual models, deal with architectural components, create objects and geometries, and use computational and parametric design. When discussing the BIM technique, the potential for creating a three-dimensional digital model is mentioned right away. Even though it is often stated in the conversation that the 3D representation of building assets is not the primary goal of the BIM application, these results are nevertheless useful. It provides the chance to clearly communicate a concept while preparing and selecting practical methods for achieving any pre-established goals. Be sufficient to state that the word BIM originally stood for Building Information Model, emphasizing the three-dimensional nature of the issue. With the advantage of being able to provide parameters like dimensions or related materials, tools with BIM potential were considered as a convenient way to avoid using CAD, which may be laborious when building three-dimensional models. Regardless of the design's graphic and aesthetically pleasing elements. A key element to remember is that the 3D aspect of BIM is primarily used for coordination. All subsequent analyses of the information model turn out to be based on 3D modelling, even though this issue is hotly contested in the literature. The effectiveness of the n-dimensional considerations is actually based on the modeming's accuracy and the addition of the essential data. Two of the core BIM methodology processes—BIM Validation—have been developed based on 3D modelling.

A technical verification that assesses the model's quality and the coherence of its components is known as BIM validation. There are two primary procedures involved in it:

- control modeling and
- check codes.

The quality of the modelling and the addition of the necessary data are what truly determine how well the n-dimensional considerations work. Based on 3D modelling, two of the key BIM methodology processes—BIM Validation—have been created.

BIM validation is a type of technical verification that rates the model's accuracy and the consistency of its parts. It involves control modelling and check codes as its two main processes.

When two or more items collide solidly, it is because they are in the same physical space. A pipe passing through a beam serves as an illustration of this type of collision. Soft clashes are those caused by two or more objects that do not necessarily collide but do not adhere to certain distance requirements, for instance. The absence of the bare minimal area required for object upkeep is a classic illustration of this type of conflict. Any more collisions can then be produced in the fourth dimension, or 4D, which takes into account the passage of time.

Conflicts in the flow of work are caused by two things that, over time, have been positioned in the same space. The application of the model(s) by various parties is in reality one of the primary factors contributing to the start of these conflicts. Due to this, it is a good idea to check for conflicts in order to prevent issues with the execution phase and the acquisition of inaccurate accounts and calculations, which could result in a delay in the execution times of the task and, most importantly, additional expenses. Code checking, on the other hand, is of an entirely different type and relates to the examination of digital models to see whether they adhere to certain rules and laws sector. This process, for instance, is used to ensure that the rooms are at least the minimum size allowed by law and that there are enough openings to meet regulatory requirements. [9]

14.3.1 Example of 3D for HVAC Systems

A 3D model provides comprehensive images of the whole structure. Here, all of the building's engineering parts, along with its structural and architectural parts, can be viewed in 360 degrees in a variety of view frames, including wire frame, fine, and rendered ones. A walkthrough, which will offer us a tour of the complete building inside and out, can be used to envision the modelled building. The tool's ability to identify conflicts between services and building components as well as conflicts between services and services within a building is its most crucial feature.

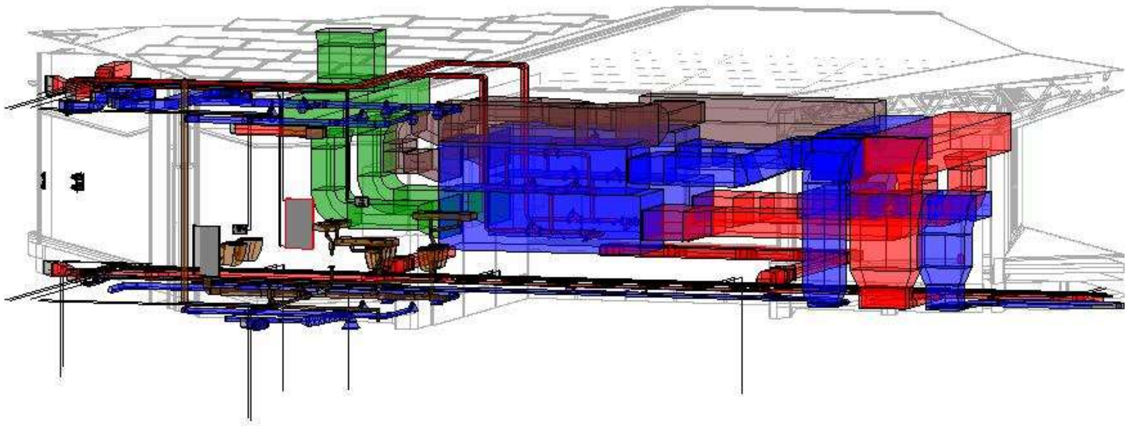


Figure 16. HVAC Design, Source: Personal collaboration

The model is imported into Navisworks, a different Revit plug-in that performs conflict detection and provides us with a visual indication of the clashes as well as the ability to generate reports. This clash detection can be carried out for the entire building at once or just for particular regions.

The entire HVAC plan for the building is shown in Fig. 16, which makes it easier to understand the ducting network and its major parts visually.

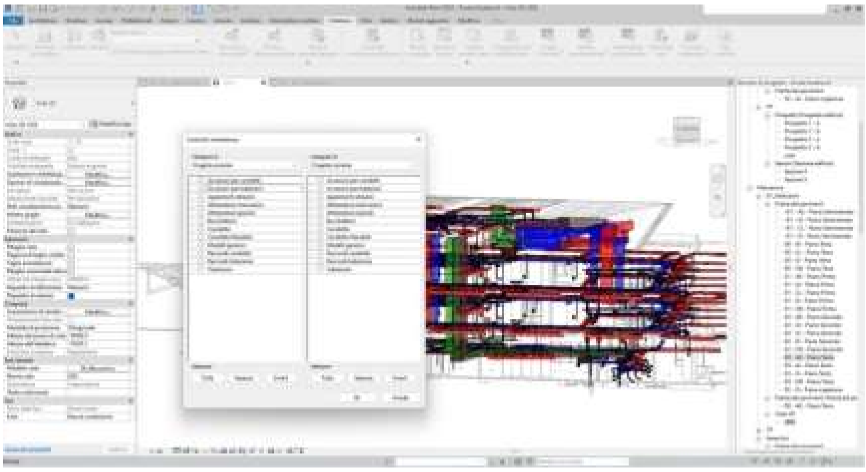


Figure 17. Clash detection test run, Source: Personal collaboration

The coordination in the project's design is flawed, which was done on purpose to highlight the conflict detection test in Fig. 17.

14.4 4D BIM

The fourth dimension of the BIM process includes model federation, virtual construction, construction planning, scheduling, and timelining. It also includes equipment deliveries and prefabrication.4D BIM has evolved into a commonly used acronym that combines a number of previously used terminology, such as 4D CAD, 4D modelling, 4D planning, and 4D simulation. Due to the fact that one of the goals of this article is to deepen the area, the topic will then be handled more broadly and will be afterwards resubmitted. The idea behind this, which is "Link a temporal scan to a three-dimensional model for improving construction planning and management approaches," is the same throughout all terminologies (Julie Jupp, 2007). Project time is a component of the fourth dimension. Their time scan, which is connected to BIM design procedures, aids in figuring out when a project will be completed and how it will progress through its many time phases. The planning, phases, and crucial construction milestones, supply logistics, installation of the products and structural components, risks, or potential uses of the building are all illustrated in the 4D display. Additionally, model-based simulations digital data on the structural durability of the building are included. The use of BIM-based technology to the 4D dimension can improve control over dispute determination and resolution as well as the complexity of modifications that arise during project construction. The 4D dimension offers management strategies that anticipate information on the condition of the construction site, the effects that changes will have, as well as how to educate stakeholders or forewarn them of any issues. The time dimension enters the 4D dimension of the BIM as briefly predicted. we can integrate all planning efforts toward the building's execution using the time dimension in BIM. Construction management is an operational area where BIM has found immediate widespread interest and as a result, one of the most widespread applications. The discipline regulates, plans, monitors, and directs the entire construction process of the building while ensuring that the requirements for time, cost, and intervention quality are met. He works with a wide range of topics, many of which are connected. [9]

Establishing processing; ensuring worker safety; taking and preserving resources.

An assessment of the jobs' progress.

Controlling processing advancements or delays.

Finding and resolving any differences between what the project stated and what actually occurred.

Willingness and observance of the restrictions that the yard must adhere to.

Unless properly correlated with design drawings that highlight the aforementioned aspects, the time planning techniques represented by the PERT and its development given by the Gantt chart, of which a brief introduction will be provided, lose their effectiveness, leading to a serious one inefficiency of the process with the concrete risk of having to potentially review the entire programming. The likelihood of data loss during document transmission from the designer to the executing company and, more broadly, the lack of communication between all interested stakeholders, are the primary causes. The BIM methodology, in a sense, offers a solution to the process's potential inefficiency because the objects of digital information models are categorized using a special restructuring that enables their identification and tracking throughout the process. Additionally, by incorporating it directly into the information model, they can be connected to these encodings' implementation-related information, enabling the deconstruction of the timetable. The most popular method of carrying out this procedure is the insertion into decomposition of the building. When this has been structured for programming-related purposes, an extension to the coding known as "activity code" is used to uniquely identify the element or series of elements that will be employed, installed, or demolished during the time phase they are related. The Gantt chart line where the items of the digital information model are put (and subsequently the activity and associated resources consumed) is made simpler by the "activity code." Overview of time scheduling Project management is a methodology and a collection of tools for ensuring the goals of:

Give reality to the practice of consultation; extend the idea of the integration of abilities in design.

Get the design players used to think in terms of "issues" and solutions.

It is a cycle tool with a set beginning and ending that enables you to subject the project to continuous testing by including:

1. Conceptualizing

2. Planning

3. Programming

4. Exercise

5. Finalize

Project management produces programming, which is a forecast and definition of the operational processes that enable the transition from project to product while maximizing time, costs, and resources. It is symbolized as a logical chain of connected occurrences that take place at two different times, the design phase, and the operational phase. The programming looks for patio-temporal connections between business, security, upkeep, and financial planning. It is instantly clear how the BIM at this point is a practical instrument is allowing the wide dissemination of information and de facto becomes an information database valuable for programming. The planning process has a high information need and requires in-depth project knowledge. Therefore, creating a trustworthy model that accurately depicts a project's progress is the ultimate objective of programming. The Gantt chart, which highlights the critical path, and the PERT, which provides a conceptual framework for the building of the Gantt but may also be utilized independently, are the two key tools employed. [9]

- The Gantt chart displaying critical path data

The Gantt method is a control and planning tool for the production process that allows for well-sequencing and visualization of the various activities to be carried out within a timing diagram that uses bars as a representation of the duration of the activities same. It is one of the most popular and perhaps one of the simplest techniques for the representation of programming. The Gantt method's structure is based on two orthogonal axes: on the horizontal axis, the time variable first appears, followed by the project's completion dates; along the vertical axis, all processing operations are displayed according to the WBS (Work breakdown structure) (hours, days, weeks, months). You must outline the steps required to finish the project, calculate the time required, and provide logical connections between the steps in order to create a Gantt chart. The PERT approach, which stands for "Program Evaluation Review Technique," makes it simple to distinguish between tasks that must be completed in order and those that can be completed concurrently. The PERT diagram shows the project as a flowchart with dependent activities represented by arrows and nodes for deadlines or pivot points. This method, which assigns three values to each value, enables the publication of three separate deadlines: the shortest (ideal estimate), the most probable estimate, and the pessimistic estimate in the event of delays or complications. The PERT method's elaborations/phases include production of the PERT based on "antecedences" defined for activities, scheduling of each activity, estimating the time of the intervention, and identifying the key path. The PERT diagram is a graphical depiction of a project's schedule that successfully clarifies expected completion dates, establishes a strict hierarchy for all required tasks, and makes dependencies between stages clear. [9]

14.4.1 Example of 4Dimension for HVAC Systems

The tool can add additional dimensions with the aid of Microsoft Project: time estimation and scheduling. When the program is fed with the tasks that need to be completed, from designing through testing and commissioning. Based on the calendar days, it will independently determine the nonworking days. This report can be plugged into Navisworks so that the work that needs to be done can be scheduled. Fig. 18 depicts the amount of time needed to complete various tasks, and the right side of the image displays the planning and scheduling according to the figures. [10]

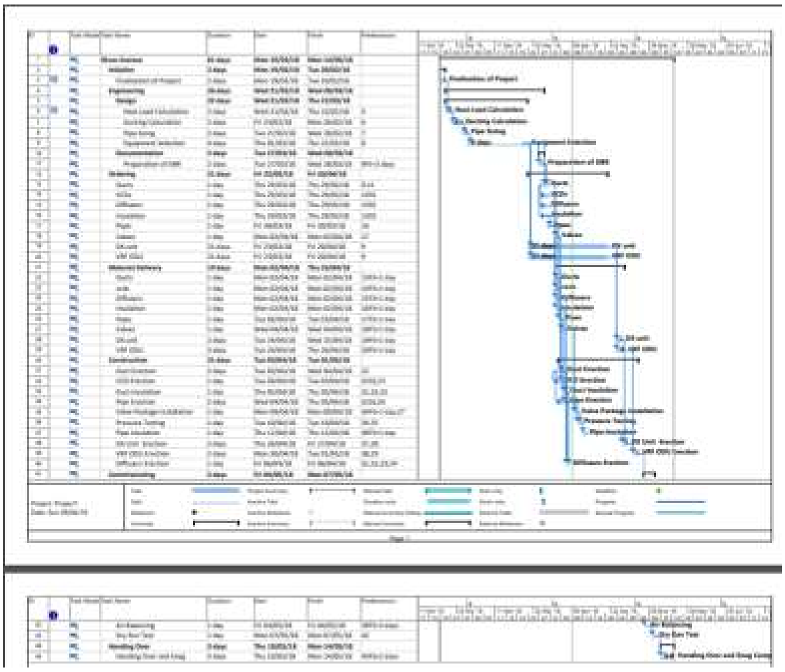


Figure 18. Time Farming and Scheduling Results. Source: Conservesolution.

14.5 5D BIM

5 dimension incorporates cost data into the BIM process. It includes detailed, cost estimation, material quantity take-off, quantity extraction, fabrication models, as well as cost comparison, logistics, what-if scenarios and building life cost. The management capabilities of the building's life cycle costs, including the expected expenses of construction and management, are assigned to the 5D dimension of BIM. Thanks to the use of the size 5D method, those who work with the computation of quantities and costs could cut down on the time and effort they expend while improving the accuracy of cost estimation. The assessment of cost is often done at phases where planning is well advanced, or even over, due to the fragmentation of the construction industry, which contrasts with the linearity of the design process. With a critical eye, it appears to be too late in the design phase for this to assist stakeholders in making decisions. In fact, this frequently results in budgetary issues that must be dealt with post-factum at the price of building quality or performance. The potential to develop a more efficient and quick project delivery process is provided by monitoring and using cost estimations from the very beginning of the process design. Greater building quality, better contractor control, and better forecasting are the results of this. Only a few domestic businesses have adopted procedures that can fully utilize the potential provided by BIM-based software for computation and cost estimation, despite the fact that this technology has been available on the market for years. One of the key responsibilities of the AEC sector and project management is cost estimation and

management. As expected, this occurs at the end of the design process by including numerous figures, information sets, and heterogeneous information. As a result, the sources appear to be exceedingly diverse, diverse and thin. Most of the time, this variability results in a significant lack of accuracy; in fact, it is common to see differences of up to 40% in terms of what can be predicted (Flyvbjerg, et al., 2003, Winch 2010). One of the promises of BIM is that it will solve this issue by offering a single source of digital information models for cost estimations over the building's whole life cycle. According to research done in 2007 by Khanzada et al, it will be able to attain error rates of 3% rather than the 40% of the prior course of action. Due to the organizational and technological difficulties in implementing BIM-based estimations, there is currently no broad documentation on implementation in the production chain despite the tremendous promises and enormous potential. BIM consists of two primary concepts: the construction of virtual 3D models utilizing BIM-based technology, and the process of shared development of design, and the creation of an information database and objects. As has been noted numerous times, the information in the digital model is made up of various pieces that each represent different aspects of the building; these elements are then enhanced with information specific to that aspects. This information can be used for the QTO process (quantity take-off) in real-time for cost estimation or to simulate building construction using the 4D dimension. After object-based parametric modelling was implemented in modelling software systems, model-based cost estimation became practicable. 2011 (Eastman). Any object in a BIM information model may have properties such as the kind and price of materials, elements, or assemblies. The quantities and numbers in the models can be abridged, but in accordance with Eastman's claim in the work "Building Information Modelling" (cited in the bibliography), [9]

14.5.1 Example of 5Dimension for HVAC Systems

The most important piece of information included in the project model to continue with execution is budgeting. Cost estimates for the selected materials and goods must be provided to determine the project's budget. As was said for the pipes and ducting, this will produce the cost assessment for the needed systems in the building. [10]

<Pipe Schedule>				
A	B	C	D	E
Cost	Diameter	Family and Type	Length	Item Cost
0.1000	2"	Pipe Types: Return	115	11
0.1000	2"	Pipe Types: Return	559	56
0.1000	2"	Pipe Types: Return	5576	558
0.1000	2"	Pipe Types: Supply	267	27
0.1000	2"	Pipe Types: Supply	864	86
0.1000	2"	Pipe Types: Supply	5423	542
				1280

Figure 19. Cost for Piping Schedule. Source: Conservesolution.

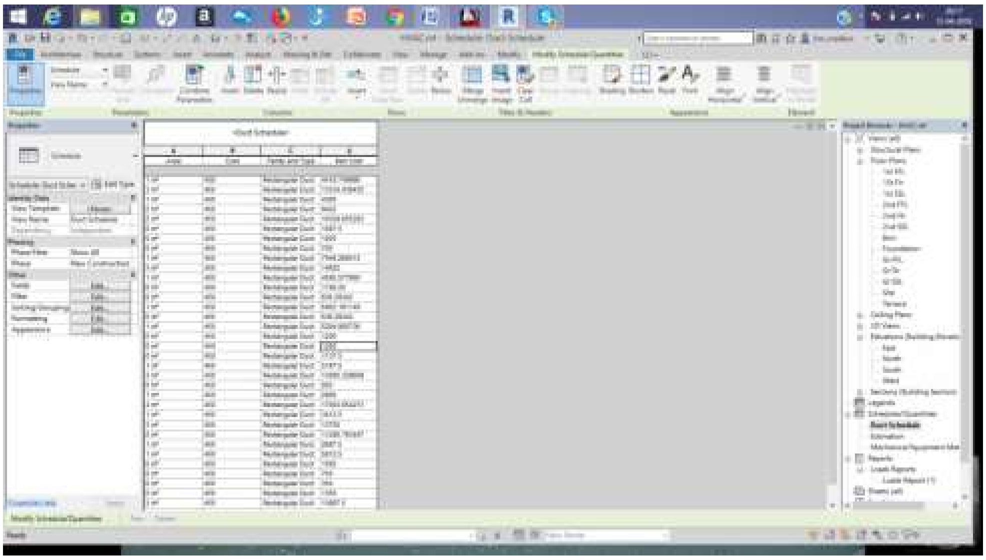


Figure 20. Cost for Ducting Schedule. Source: Conservesolution.

14.6 6D BIM

The performance of energy use and sustainability are extrapolated in the sixth dimension of BIM. We can evaluate our structures using 6D in comparison to several energy rating methods. The definition of the 6D dimension in the literature is still unclear; it is frequently linked to the life cycle of the building with an eye toward environmental sustainability, while other times it is connected to the skill of facility management, which is typically ascribed to the 7D dimension. The 6D dimension will be made to be treated as that dealing with sustainability in this brief talk, while the 7D dimension that relating to facility management. The building's life cycle is represented by the 6D dimension, which includes elements linked to: [9]

- Sustainability measures like energy assessments,
- deconstruction,
- and the removal or recycling of building materials

The adoption of the 6D BIM dimension is closely linked to the development of a fresh sensibility toward sustainability, such as the outcome of growing knowledge of the world's environmental issues. The building sector influences social and environmental factors in all economies. In fact, the dimension to which it is most closely related is that relating to 4D, where the characteristics of sustainability and the very concept of the building's life cycle, of course, yes, evolve over time having a wide range of consequences. As with the other dimensions of BIM, 6D can concern or enter the areas of competence of the other dimensions of BIM. The designers have benefited from integrating the application of BIM to sustainability, generating significant achievements in the implementation of the design of buildings with extremely high sustainability performance. BIM, when viewed through a 6D lens, enables decisions to be made appropriately from the very beginning of the design process, allowing for comparison and integration with sustainability-related elements like the analysis of exposure, natural ventilation or mechanics, hydraulic efficiency, the effect of heating, and renewable energies. When the decision-making process is complete, the chosen alternative is chosen, and the decisions made are validated. Therefore, dealing with the 6D dimension of BIM and the life cycle aspects is a possible state without using too much approximation. When it comes to this scope of approximation, however, the debate of the sustainability of the building is truly referred to. Citing findings from the section of the seventeenth international conference on cells solid fuel that discussed the integration of 6D-oriented BIM models for building sustainability: BIM has recently made it possible to directly classify and certify more than 13 credits, which is a prerequisite of the LEED protocol assessment system. According to certain studies, using the BIM technique necessitates the assignment of an additional 17 credits and two Leadership in Energy and Environmental Design (LEED) protocol prerequisites. During the symposium, the following functions of BIM in sustainability were defined:

- Environmental:

The AEC is now aware of the impact that BIM has made to design integration and quality enhancements; this has also made it possible to consume less energy and material. It enables the user to assess the building's whole life cycle and, using the evaluation's data, perform comparison analyses for various solution planning. By utilizing BIM-based software, designers might forego the traditional environmental effect calculation methodology in order to approach an "experimental" strategy and be able to quickly conduct assessments at important periods.

- Economic:

As stated in the 5D component of the treatment, the BIM technique may be used to swiftly generate cost feedback throughout the life cycle of a building. The creation and preparation of the digital information model demands the cooperation of engineers and architects. BIM obviously, by its nature, gives more details in less time while being more cost-effective. The BIM approach streamlines and improves the estimation process. The ability to do quantity takes offs, establish the pricing required for cost estimating, and calculate the amount of materials actually used in construction are all capabilities of BIM-based software. The amount of information available on the information models is frequently positively connected with the estimate's accuracy. [9]

- Social:

There are leaning connections between BIM and social sustainability. like the internal localization algorithms that BIM created to enable the response to an emergency fire, as an example. The impact of the total temperature and humidity on the project was also simulated using the critical path method (CPM). A forecasting system for the concentration of air pollutants during the construction phase might be made using the BIM as well. One further, less significant outcome of BIM is that it might suggest a quality inspection method for the safety of buildings to solve some issues linked to the social sustainability of the built environment. Going in this direction Even yet, there is still a sizable research gap to be filled in relation to more established approaches. The development of a model 6D capable follows a 3-step process in compliance with UNI EN ISO 14040 for LCA requirements: [9]

- An explanation of the purposes and goals

The ultimate objective is to establish an integrated 6D model for carrying out sustainability assessments throughout the building's life cycle as a decision-support tool for designers.

- Impact assessment model development and analysis in 6D

The simulation phase, which covers a variety of design domains and includes energy, safety, and prevention, is what may be inferred from the above. Since performance and evaluation must take into account the change through time, this stage must necessarily comprehend by treating the L.C. and 4D areas.

- Results interpretation

The diagram that follows provides an excellent summary of what was just spoken; it shows a procedure that, in turn, finally enables one to take into account a building's complete life cycle.

14.6.1 Example of 6 Dimension for HVAC Systems

The information regarding the building's thermal performance will be shown in the sixth dimension. The air conditioning system typically uses the most power in any conventionally air-conditioned building; therefore, by taking a little effort to reduce energy usage, will result in significant savings over time. [10]

The primary goal of this simulation of a building's energy use is to forecast the HVAC system's monthly and yearly energy consumption in relation to thermal comfort and indoor air quality. [10]

The sixth dimension will display data about the thermal efficiency of the building. In a building with conventional air conditioning, the air conditioning system normally consumes the most energy; consequently, making a small effort to cut energy use will yield big savings over time.

This simulation of a building's energy use's main objective is to predict how much energy the HVAC system will consume each month and year in relation to thermal comfort and indoor air quality. [10]

Envelope Characteristics			
	U-Factor with Film [W/m2-K]		
Base wall	2.1		
Base roof	3.9		
Floor	0.25		
	Glass U W/m2-K	Glass SHGC	Glass VT
Window	1.96	0.69	0.74

Figure 21a. Energy consumption Pattern. Source: Conservesolution.

Internal Loads	Value
Occupant Density (m2/person)	0.022
LPD (W/m2)	5
Equipment load (W/m2)	3.58
Infiltration (ac/h)	0.55

Ventilation	
Fresh air (l/s-person)	10
Mech vent / area (l/s-m2)	10

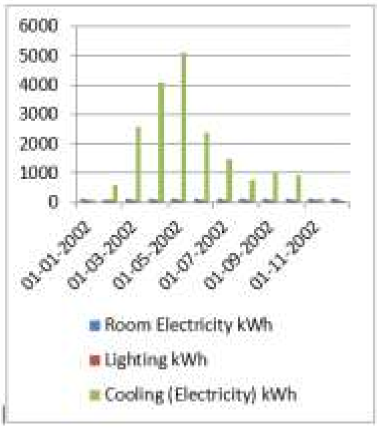


Figure 21b. Energy consumption Pattern. Source: Conservesolution.

14.7 7D BIM

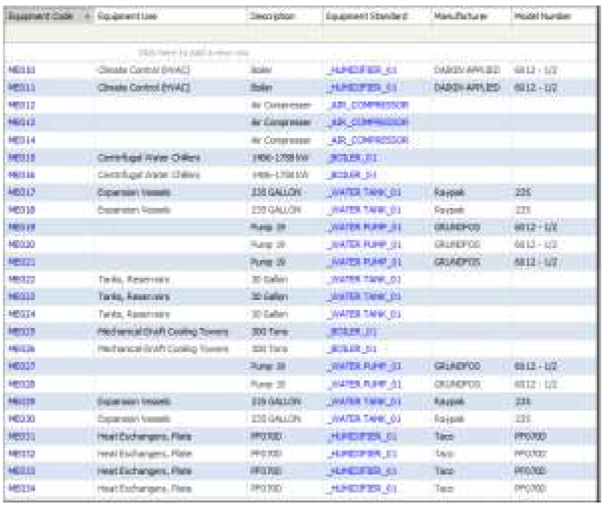
Facilities management is the seventh dimension of BIM. It concentrates on both building maintenance and life cycle analysis. [9]

The facility management (FM) component, sometimes known as "building management," is represented by the 7D model in relation to economic, environmental, and social issues. This dimension includes all management activities, building upkeep, and renovations. BIM is described as "an IT-enabled method" that uses and applies a comprehensive digital representation of all the building information in the form of a repository for each stage of the building's life cycle. 2021) (Md. Tanjid Mehedi). According to the findings of several market studies, a significant number of public and private contractors claim that the adoption of BIM-based capabilities for the operational phase of the buildings in which they are stakeholders is of fundamental interest and importance. Again, in line with the foregoing, the comprehensive information represented by a digital information model is essential for the building's upkeep and operation. Although there are still certain areas that need to be researched, the management of existing structures sees the use of Building Information Modelling (BIM) as a chance for innovation and development. Digital information models for buildings enable the integrated and partially automated collection, generation, analysis, and communication of a variety of information and data. Facility management, which is represented by the seventh dimension of BIM, is defined by the IFMA (Institute Facility Management Association) as "a business discipline that coordinates the physical workspace with the resources human resources and the company's own operations and integrates the principles of management business economics and finance, architecture and the sciences behavioural and engineering sciences." For this dimension to develop, as-built models were necessary. [9]

14.7.1 Example of 7 Dimension for HVAC systems

Another important aspect of BIM is primarily discussed to the maintenance of the building's HVAC system. [10]

In the ARCHIBUS-Revit integration as an example, all electrical components, such as electrical panels, circuits, lighting, receptacles, control systems, and more, may be simply maintained and retrieved. By utilizing pre-defined component standards and critical data such as the model number, power requirements, heat load, and vendor information, ARCHIBUS can quickly produce a full electronic inventory of the HVAC systems of the site. Check the circuit and panel loads and component counts, and use the built-in reporting system to calculate reporting by building, floor, and room. During the operation level, overloaded circuits and other potential issues can be avoided. [10]



Equipment Code	Equipment Use	Description	Equipment Standard	Manufacturer	Model Number
ME010	Climate Control (HVAC)	Boiler	_HUMIDIFIER_01	DAIKIN APPLIED	6812 - 1/2
ME011	Climate Control (HVAC)	Boiler	_HUMIDIFIER_01	DAIKIN APPLIED	6812 - 1/2
ME012		Air Compressor	_AIR_COMPRESSOR		
ME013		Air Compressor	_AIR_COMPRESSOR		
ME014		Air Compressor	_AIR_COMPRESSOR		
ME015	Centrifugal Water Chillers	1406-1758 kW	_BOILER_01		
ME016	Centrifugal Water Chillers	1406-1758 kW	_BOILER_01		
ME017	Expansion Vessels	235 GALLON	_WATER TANK_01	Raypak	235
ME018	Expansion Vessels	235 GALLON	_WATER TANK_01	Raypak	235
ME019		Pump 39	_WATER PUMP_01	GRUNDFOS	6812 - 1/2
ME020		Pump 39	_WATER PUMP_01	GRUNDFOS	6812 - 1/2
ME021		Pump 39	_WATER PUMP_01	GRUNDFOS	6812 - 1/2
ME022	Tanks, Reservoirs	30 Gallon	_WATER TANK_01		
ME023	Tanks, Reservoirs	30 Gallon	_WATER TANK_01		
ME024	Tanks, Reservoirs	30 Gallon	_WATER TANK_01		
ME025	Mechanical Draft Cooling Towers	300 Tons	_BOILER_01		
ME026	Mechanical Draft Cooling Towers	300 Tons	_BOILER_01		
ME027		Pump 39	_WATER PUMP_01	GRUNDFOS	6812 - 1/2
ME028		Pump 39	_WATER PUMP_01	GRUNDFOS	6812 - 1/2
ME029	Expansion Vessels	235 GALLON	_WATER TANK_01	Raypak	235
ME030	Expansion Vessels	235 GALLON	_WATER TANK_01	Raypak	235
ME031	Heat Exchangers, Plate	PF0700	_HUMIDIFIER_01	Taco	PF0700
ME032	Heat Exchangers, Plate	PF0700	_HUMIDIFIER_01	Taco	PF0700
ME033	Heat Exchangers, Plate	PF0700	_HUMIDIFIER_01	Taco	PF0700
ME034	Heat Exchangers, Plate	PF0700	_HUMIDIFIER_01	Taco	PF0700

Figure 22. Building Floors with HVAC and Piping in ARCIBUS Central. Source: Conservesolution.

Establishing a communication link between Revit and ARCHIBUS is the initial stage in data transmission. The database link joins the Revit model to an existing project (building and floors). This background data, including the building asset, its location, and its organizational characteristics, must be present for a link to be attempted. Following the creation of the link, this data is categorized and synced between Revit and ARCHIBUS. [10]

15 BIM in The Project Lifecycle

Pushing the boundaries to build links and integrate data to handle the entire building lifecycle from early visibility and planning studies, design, construction, operation, and maintenance, to demolishing, is the challenge that lies beyond the 3d, 4d, and 5d.

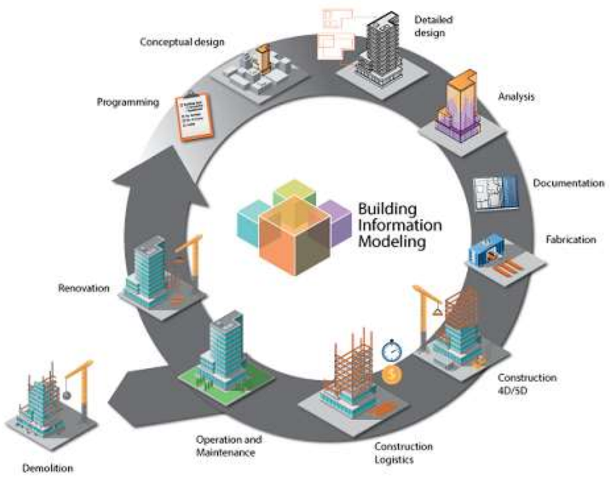


Figure 23. BIM Lifecycle. Source: Autodesk

15.1 Construction

Different perspectives on project management for construction are gained by each person participating in the process of planning, designing, funding, building, and operating the physical facilities relevant to the project at hand. Particularly when it comes to huge and complex projects, the input of qualified expertise can be quite advantageous because professionals in many fields can provide beneficial services. On the other hand, it is crucial and beneficial to comprehend how the various components of the process work together. Waste, extra expense, and delays may emerge from the professionals' inadequate collaboration and communication. The owner has a responsibility to ensure that these defects do not arise between them. Furthermore, it is the responsibility of all project participants to take into account the interests of the owners because, in the end, it is the owners who provide the resources and make the decisions. By paying close attention to the project management process for built-in facilities, the implementation of the owner's viewpoint will assist the participants in concentrating on the project's completion. This will reduce the use of the outdated idea of basing judgments on the previous responsibilities of professionals involved in the project.

In general, a typical construction project goes through the five primary life cycle phases listed below:

1. Initiation

2. Planning

3. Execution

4. Performance and observation

5. Closure

15.2 Operation:

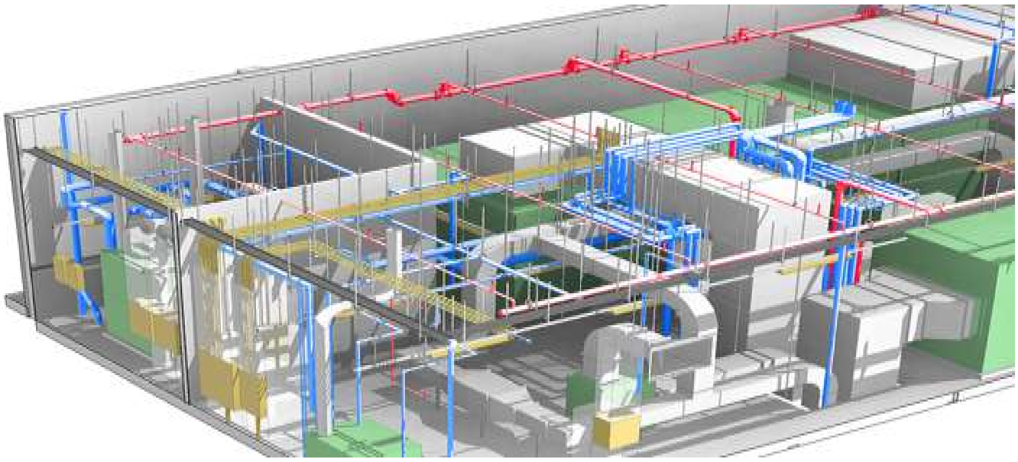


Figure 24. BIM operation of HVAC system

The objective of operational BIM is to extend the use of BIM to assist the productive activity of the specific facility and rationalize its usage in long-term building operations. Simple and durable tools like laser distance meters for the floor plan and barcode/RFID readers for the inventory with all necessary supplementary data, including pictures, must be used to simply survey it. It is crucial that updating these building and asset data be simple, handled by the usual operational crew without requiring a lot of their time at the location of operation or repair, and integrated into their daily tasks. Integration is a crucial component defining the effectiveness of BIM in practice. Any software programs, workflows, and procedures requiring building or asset data on-site or in the office must be able to integrate operational BIM. Therefore, if a maintenance worker has to locate equipment, a floor plan or 3D model for going there must be provided on-site, but a decision maker needs to be able to view a rental report in colour from any location using a basic web browser. Multiple users should be able to access and modify this data simultaneously on-site. The "building history" should be preserved in log files since Operational BIM is intended to track any modifications made to a building or an object contained inside it. Our main objectives in creating the OrthoGraph Enterprise ecosystem have been to meet all of these requirements. Operational BIM boosts the productive performance of the relevant facilities while producing significant cost reductions in daily operations. Learn more about the advantages of adopting operational BIM for facilities other than facility management, such as office buildings, malls, hospitals, and production facilities.

15.3 Maintenance:

In addition to producing 3D virtual models, BIM technologies also make it easier for stakeholders to work together. The management of stakeholder input over a project's whole lifecycle is the main goal of BIM. Additionally, because building operational phases can endure for decades, BM (building maintenance) operations change with time to ensure the provision of a quality service when items and technology become universal. Therefore, obtaining appropriate and readily available information is a major obstacle before starting maintenance activities. Numerous BIM-focused studies are being conducted to enhance BM procedures, which are occasionally regarded as components of Facility Management (FM) systems. Locating components, making access to real-time data easier, assessing maintainability, producing digital assets automatically, ensuring quality, managing energy use, and managing space are just a few examples of application areas. Applications examples include AROMA-FF, which is designed to use data from BIM databases to obtain information and geometric representations of facilities and equipment, the web-based Facilities Maintenance Management (FMM) prototype decision support system, and the BIM-based package for the FM Exemplar project of the Sydney Opera House are all examples of digital data management tools. Fundamental procedures for Asset Management, Corrective Maintenance, Preventive Maintenance, and Condition-based Maintenance form the foundation of FMM. The knowledge acquired during the stage of maintenance and operation of buildings, which can also be captured and be transferrable through a BIM model, is generally not targeted by BIM-related systems, which are primarily focused on utilizing technical information and allowing access to multiple databases. Therefore, applying knowledge management (KM) principles can aid in BM performance reaching new heights of efficiency. By doing so, the BIM systems will be able to expand from their current emphasis on technical and geometric data to include non-technical and non-geometric knowledge related to building processes.

15.4 Demolishing:

The Architecture, Engineering, and Construction (AEC) sector is seeing a transformation because to BIM. The "digital representation of physical and functional properties of a facility" is how it is described (NBIS 2015). It is the process of creating and managing project-related data across the course of the many construction life cycle phases. The information extends to include any customizable information pertaining to the building and includes not only the geometric attributes of the building's components. BIM has a variety of applications, such as: Quantity take-off, 3D visualization, 4D scheduling, etc. Although there is a lot of study being done on the usage of BIM features, there aren't many ways to leverage it to your advantage during the deconstruction stage (Krygiel and Nies 2008). Due to the high amount of uncertainty associated with the process, planning for deconstruction projects is difficult (Hübner et al. 2017). For instance, the goods that need to be disassembled have unique properties and a combination of parts from several technical life cycles (Fletcher et al. 2000). These "meta-products" have various characteristics and cause a number of issues throughout the disassembly process. These issues are also a result of the structure's lengthy lifespan, which includes numerous renovations and adjustments. These changes are typically not documented when the building is deconstructed. Therefore, it's essential to have a platform that can record the current condition of the structure that will be torn down. Additionally, such projects are thought to have resource-limited scheduling. Due to limits on time, environment, safety, space, and costs, the project schedule must take into account the optimization of a number of criteria to guarantee that the production flow is in sync with end-customer requirements. The selection of the best deconstruction scenario during the design of this intricate scheduling is aided by a data-rich environment with simulation capabilities (Hübner et al. 2017). Consequently, a central location is required for integrating data from various sources (like on-site sensors, documents, drawings, etc.). The central hub required for data integration can be provided by information model building (Tarandi

2011). Through correct description of the present situation and visualization, it can also considerably aid in decision-making (Volk et al. 2018). Consequently, employing BIM tools and processes can reduce the uncertainty present in current techniques (Hübner et al. 2017).

16 Recognizing BIM roles in a project cycle

The design team is nearly always the only group that BIM and its tasks are associated with in its earliest forms. However, a detailed examination of its development over the previous 50 years would show that the field of project management is where BIM has found the most sustained use (National Building Specification, 2015).

Early forms of computer-assisted designing and building information modelling have been used by designers since the 1980s (BIM). However, due to the conceptualization and development of BIM definitions, the delivery of collaborative projects is its ultimate objective and greatest advantage.

17 Guidelines for BIM Specialist Roles

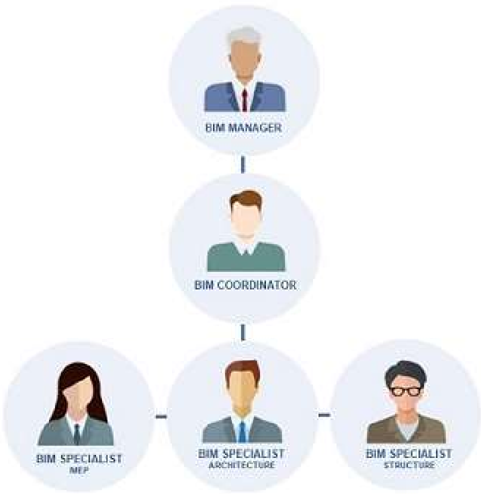


Figure 25. BIM Roles. Source: biblus

According to the Norwegian House Builders Association BIM Users' Manual (BoligBIM, 2012). The sections of each BIM guide that addressed roles and duties were taken out and tallied in accordance with each role's main definitions or descriptions. In order to find a consolidated set of jobs and the related areas of influence or responsibility connected with each, these were grouped by the significant terms utilized. These are not necessarily expected to be exclusive or self-contained positions within a company or project, and "in certain organizations, the same person will be able to fulfil many of the roles," [11]

17.1 Role Definitions:

There are many different job titles that apply to BIM professionals, as Barison and Santos (2010) found from the technical literature and later discovered in an examination of BIM job advertisements (Barison and Santos, 2011). Through a comparable analysis of job listings, Uhm, Lee, and Jeon (2017) found 35 job kinds, many of which had identical requirements and descriptions. These positions fall into two categories: organizational roles, where the primary function is carried out at the corporate level, and project roles, where the primary function fits inside a project team. The analysed BIM guides and standards very rarely distinguish between organizational level and project level role definitions, although they frequently include descriptions of tasks or expectations that are obviously organizational rather than project-based. Based on an interpretation of the various areas of activity, a distinction has been formed from the responsibilities indicated in the reviewed BIM manuals. The two primary groups of BIM roles with a project integration component have very uniform scopes and responsibilities. These typically consist of a broad project management and coordination function, which is backed up by a second tier of specialized managers or BIM coordinators from each of the design and construction teams or technical groupings. The organizational BIM manager and the BIM modeller/author are two other categories that can be derived from some handbooks that specify BIM roles that are concerned with organization-level BIM procedures. Only three of the 35 manuals investigated the BIM responsibilities for defined clients, assets, or facilities management. [11]

17.2 BIM Manager – Project Role

The project level BIM manager position is the one that is most frequently mentioned. The individual or individuals playing this function may represent the principal contractor, the principal designer, or a third party operating on the client's behalf. At this level, the BIM Manager is in charge of creating the BIM execution plan, delivering it, and defining BIM guidelines for the project. The majority of descriptions include keeping oversight over BIM tasks and deliverables as part of the function, along with quality assurance. An essential component of this function is managing project data and facilitating the collaboration process, which includes planning BIM project meetings. The level of authority exercised by the BIM Manager in a project is one area where potential misunderstanding exists. The position is frequently defined in terms of the stage of the project, such as the Design BIM Manager or the Construction BIM Manager. These roles are anticipated to report to the Project Manager, who serves in an oversight capacity, particularly in papers based on the BIM Guide. The BIM Manager function, which is the overall project role in many of the documents, is expected to be shared by several parties depending on who is in charge of each stage of the project. [11]

17.3 BIM Coordinators – Project Role

The BIM Coordinator is referred to as a supporting position working under the direction of the BIM Manager and acting as a representative of each distinct discipline within the project framework. Model Manager is a common term for this position, particularly for sub-trades and specialized consultants. The BIM Coordinator is in charge of ensuring that BIM models developed within their team adhere to the established BIM standards and exchange procedures, as well as facilitating the sharing of BIM models from their company or field. The BIM Coordinator's responsibilities frequently include model coordination and clash detection; The BIM Manager oversees the coordination activity within a project team, however each BIM Coordinator is in charge of managing and coordinating their individual model as well as any necessary propagation of modifications. Quality control, ensuring that the discipline model adheres to the standards agreed for the project, providing guidelines for the discipline team on agreed project requirements, and communicating data transfer needs and processes with other disciplines are additional duties listed for the BIM Coordinator role. [11]

17.4 BIM Manager – Organizational Role

While almost all of the manuals and guides examined are focused on the project-level procedures involved in BIM implementation, several of them also outline the job of a BIM Manager in terms of organizational duties in addition to project duties. This typically includes accountability for training as well as problems with hardware and software. The BIM Project Manager's responsibilities, for instance, are listed in the Hong Kong BIM Project Specification (HKIBIM, 2011) as training and technical support for modelling employees. Similar to this, the New York City Department of Design and Construction BIM Guidelines (NYC-DDC, 2012) specify the BIM Manager role primarily at the project level and in terms of interaction with NYC-DDC as the client. However, it also specifies the level of proficiency the BIM Manager must have in the chosen authoring tools and gives them the duty of organizing BIM training. The BIM Manager for an organization is frequently also the BIM Coordinator (i.e., the discipline-specific BIM representative) at the project level, hence it is usual for the same person to handle both organizational and project-related duties (Davies et al., 2014). However, as these are not project-level requirements, the client is not required to specify them in order to adopt BIM successfully. [11]

18 BIM in Numbers

Although BIM has received a lot of attention over the last several years, there is still more work to be done before we can say that the construction sector is making the most of its application. [12]

In an interview with BIM+, Darren Smith, a digital buildings solutions adviser at the Electrical Contractors' Association, shared some extremely intriguing figures and facts about the relationship between the sector and BIM:

In the 2018 Building Engineering Business Survey, 69% of ECA members who took part confessed that they had never worked on a BIM project.

24% of those who have experience with BIM had only used it for a maximum of three months.

Mr. Smith emphasizes the fact that there are surprisingly few businesses that have adopted BIM projects. More particularly:

• Roughly 4% of the organizations surveyed have used BIM on 25–49% of their projects.

• At the same time, only 2% of projects at that company were using BIM.

• And last, only 1% of the companies that took part in the survey had adopted BIM in 75% of their projects.

The numbers of engagement are actually not that awful, as Darren Smith notes that Electrical Contractors seem to be ahead of the curve in comparison to other areas of the construction business.

This shows that there is still much space for development in the construction industry and indicates that there will be greater results if stakeholders decide to take a more proactive approach to BIM.

They will be able to directly experience some of the greatest advantages of building information modelling in this way:

- A 33% decrease in the cost of construction and the project's lifecycle.
- A 50% reduction in the lifecycle of a project from inception to conclusion.
- A considerable reduction in the amount of materials utilized during construction.
- Enhancements in terms of security and health.
- Risk reduction and increased predictability throughout the construction process.
- A less fragmented supply chain with improved information flow.

It quickly becomes apparent that BIM might have a multi-level impact on the construction sector and aid in the fight against low productivity, high rework rates, and negative margins. [12]

19 The Future of BIM in The Construction Market

The usage of BIM is accelerating and the industry growth is being driven by the increasing demand for quick infrastructure and housing construction due to the growing global population. Since the construction sector is one of the most accident-prone industries, BIM is being used more frequently to identify possible risks and hazards, hence enhancing worker safety.

BIM is used to provide cost modelling while promoting cost-effectiveness, thereby boosting the market for BIM in construction. This is in response to the growing need to accurately estimate cost information for building construction. The construction industry's growing usage of cloud-based BIM to improve cost effectiveness and optimize workflow is driving market expansion. Cloud-based BIM's broad accessibility facilitates the fast sharing of information. Additionally, it increases the versatility of construction modelling, which is why it is becoming more and more popular.

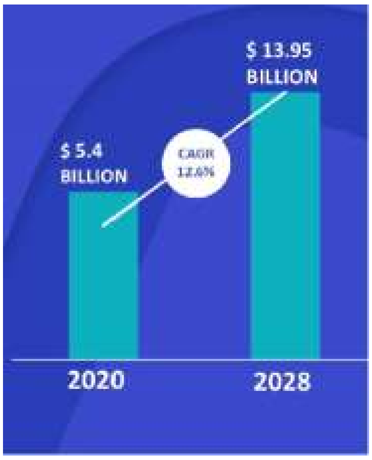


Figure 26. BIM statistics. Source: verifiedmarketresearch

In addition, it is anticipated that the development of cloud-based BIM, which offers improved safety and security, will support the growth of BIM in the construction sector in the upcoming years. In 2020, the market for building information modelling was estimated to be worth USD 5.4 billion, and by 2028, it is expected to be worth USD 13.95 billion. During the predicted period, a CAGR of 12.5% is anticipated. The building information modelling market is expanding as a result of COVID-19's increased acceptance of remote working, urbanization's rapid rise around the world, the AEC industry's wide-ranging BIM benefits, and expanding government measures to implement BIM. The expanding focus of businesses on introducing new standards in the BIM market, the rising trend of It in the construction sector, and the rising trend of BIM all present growth opportunities for market players.

20 BIM in The Project Cycle

Building Information Modelling (BIM) is described as "a digital representation of physical and functional aspects of a facility" by the US National Building Information Model Standard Project Committee. When used as a solid basis for decisions throughout a facility's life cycle, which is defined as existing from the time of initial conceptualization through demolition, a BIM is a shared knowledge resource. [3]

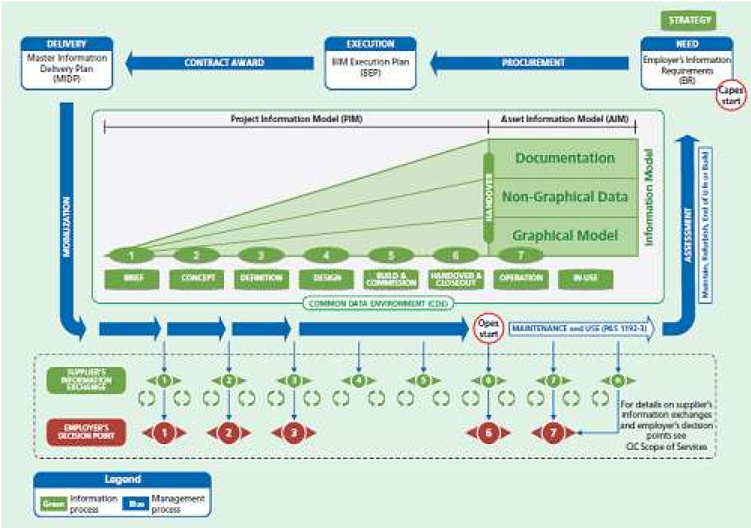


Figure 27. BIM in project cycle. Source: Autodesk

The committee also noted that, practically speaking, BIM can signify a variety of things, depending on the viewpoint:

20.1 Information Components in The Design Phase

The information that is created during the design phase, which is mostly dependent on the actions during the design phase, is included in the D-BIM. Through an implementation model, the design phase aims to illustrate the clients' construction goals, including the functional specifications and standards of the proposed project. To maximize the owners' aims, the design tasks demand a multidisciplinary collaborative working technique. Owners coordinate, create, and sign the bid and contract documents with designers, consultants, supervisors, contractors, and other parties are among the primary activities in the design stage. To conduct the hydrogeological investigations and to create the design specification, timeline, and design estimates, the owners hire a survey and design firm. Additionally, they organize contractors and managers to evaluate construction drawings and audit the preliminary design and technical design. They next secure the government agency in charge of construction plans' approval. It is crucial to make sure that the data may be used by a variety of people to facilitate interdisciplinary collaboration and boost operational effectiveness. According to the design content, we divide the data collected during the design phase into six categories: public information about the project, information pertaining to related projects, location information for the proposed project, survey, and design data, bid and contract data, and economic data. [3]

20.2 Information Components in The Construction Phase

The information generated during construction activities is included in the C-BIM. Due to the dynamic nature of construction control and management, there is more information available in the C-BIM. The owner, design firm, supervising firm, general contractor, subcontractors, material suppliers, equipment suppliers, and pertinent government agencies are all involved in this lengthy and complex project. Additionally, there should be a substantial amount of people and material resources available for usage throughout the construction period. Projects can be divided into three sub-phases during the construction phase, which is the act of putting a construction together: preparation, construction, handover, and defective obligation sub-phases. The preparation sub-main phase's activities include securing building permits and details on rules and technical requirements, selecting a supervision unit and subcontractors, signing construction contracts, organizing, and reviewing drawings, operating software, and describing design and technical aspects, etc. [3]

Construction implementation management, which includes site management, resource management, schedule management, cost management, quality management, as well as generally assuring safe and civilized management, is the crucial work in the construction phase. The delivery of the project, the commissioning of the facilities and equipment, the acceptance of the materials for completion, and the preparation for the property transfer are the major tasks of the handover and faulty obligation sub-phase. Since these operations generate a variety of complicated information, it is possible to broadly divide it into three categories: general information, organization-specific information, and project-specific information. The general information category describes information that is readily accessible to the general public about building materials, rules, protocols, the environment, etc. [3]

All information that is available to a particular organization is categorized by the organization-specific information, which frequently takes the form of a library of previously finished projects that the organization uses as reference cases. Examples of this information include standard solutions to design-construction problems. This can include details about initiatives that are similar. [3]

The supply chain's various companies share the project-specific data, which is related to a single type of construction project or project in general. The handling of project-specific information during the project's actual construction stage on site is the subject of this study. General situational information, organizational information, construction management information, technical information, resource information, and environmental information are all examples of project-specific information. [3]

20.3 Information Components in The Operation Phase

The maintenance of construction projects' operations is known as operation management. In addition to offering users a stylish and comfortable atmosphere, good operation management will also guarantee the functioning of the equipment in the buildings and achieve sustainable applications.

Maintenance of buildings and facilities, daily maintenance, and management of construction equipment (electricity, heating, ventilation, air conditioning, elevators, etc.), operations management units signing a contract with the user, keeping structures in the immediate area clean and green, public security management, personnel file management, creation of rules and regulations, and maintaining the fee are the main tasks involved in the operation phase. General information, project-related information, and facilities management information are the three categories into which operation phase information can be divided. The term "generic information" refers to information that is available to the public regarding national and local laws and regulations, including the numerous rules made by the responsible department. The takeover information, contract documents, record information, and project situation are all included in the project-related information. All information that the facilities management has access to during the operating phase is categorized in the facilities management information, including information about users, the environment, buildings, equipment, the economy, public security, disaster preparedness, etc. [3]

21 Integrated Project Delivery (IPD) and BIM

IPD and BIM are entirely compatible with one another in construction projects, according to the American Institute of Architects Guide (Ashcraft, 2008): [13]

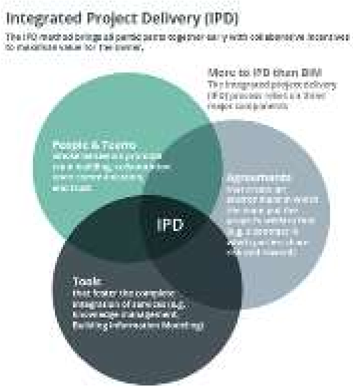


Figure 28. Integrated project delivery in BIM. Souce: vjscozzariandsons.

Building information modelling (BIM) and integrated project delivery (IPD) are recognized as two distinct concepts; IPD is a method, while BIM is a tool. Undoubtedly, BIM is used in non-integrated processes but is not employed in integrated projects. But only when they are utilized in tandem can IPD and BIM deliver all of their potential advantages. [13]

21.1 How Does Integrated Project Delivery Work?

A multi-party system between the owner, designers, contractor, subcontractors, and other important trade entities is used in IPD, a new project delivery model, in order to foster cooperation and collaboration. IPD was created as a way to forecast an asset's total lifecycle cost and lower the risk of cost overruns during project construction (infrastructure project). The preference for IPD in projects has developed within the US construction sector.

A multi-party contract between the following parties makes up the IPD project team:

- All main players, including
- the owner
- contractor
- designers
- facilities manager

and major trade contractors (mechanical, electrical, fire, and plumbing), have direct contractual relationships with one another and will be held to enforceable responsibilities with respect to (Stirton, 2015):

- Intellectual property ownership and licensing
- confidentiality
- liability, both to one another and to third parties
- and insurance
- Dispute resolution techniques

IPD project teams are established during the conceptual stage of a project, and before beginning construction, all parties involved collaborate to create a "built asset" in BIM. IPD recommends using platforms like BIM or other collaborative environments that enable the IPD project teams to readily collaborate with one another to address "buildability" issues or unanticipated hazards that would arise during the building phase. Using IPD necessitates a change in the way projects are delivered; owners must invest more time and pay money up front (when compared with the traditional design-and-construct delivery model). However, because of this early investment, design difficulties have already been fixed before construction even begins, design alternatives and associated costs have already been discussed with the construction teams, and as a result, a much more reliable construction schedule and cost are determined (Stirton, 2015).

BIM and IPD work best together because they improve project management by fostering greater stakeholder collaboration and data sharing (Stirton, 2015):

- less chance of errors and their correction
- less material wastes.
- decreased problems with building

IPD is the method that encourages parties to easily exchange information, ideas, and intellectual property (Stirton, 2015). This results in effective and efficient delivery throughout the course of the project when combined with BIM. Because all parties are required to share protected intellectual property to produce project outcomes, this system eliminates the "we vs them" mentality. Unexpected changes in circumstances can be accommodated by the IPD-BIM technique. The Edith Green Wendell Wyat Federal Building refurbishment in Portland, Oregon, is one instance of this. The west facade had to be completely redone in 7 weeks due to a significant design issue that arose during construction.

Because everyone involved in the project had a stick in its success rather than just looking out for their own interests, the project team was able to overcome the delay. The functions of BIM in an IPD cycle in an integrated project delivery, there are seven phases where BIM is crucial:

1.Designing conceptualization (programming) criteria (schematic design)

2.Design in depth (design development)

3.Documentation phase of implementation (construction documents)

4.A company review

5.Buy-out

6.Construction (contract administration) (contract administration)

7.Close-out

BIM's roles can be broadly classified into seven categories in these seven phases (Autodesk):

Making judgments is substantially enhanced by using BIM models and BIM tools throughout design and construction to reduce bad design decisions.

Contract Documentation: Contract documentation is improved by lowering the percentage of unknowns in the documents and utilizing BIM to re-establish accuracy and precision and enhance construction cognition and assembly comprehension of all project participants.

A preliminary estimate Pre-construction estimating is significantly improved by using schematic design take-offs produced by the BIM process to reduce the amount of guesswork and inefficiency. Additionally, the contractor may apply various pricing models and reuse already-built digital models in new areas. Scheduling and Purchasing: By using time modeling and cost modeling (BIM 4D/5D), procurement and project scheduling can be reformed to reduce downtime on the job site and enhance subtrade coordination, overlap, and phasing. Coordination: By integrating the main design model early in the process and using clash detection software to support interdisciplinary design coordination, coordination concerns can be resolved virtually rather than in the field. Cost Effectiveness: By adopting a pre-fit workflow from the designer to the subcontractor and demanding greater installation precision, it is possible to significantly increase economic effectiveness by reducing the cost consequences of coordination errors, faulty production, and improper installation. By optimizing project timelines that lead to quicker construction, using BIM in the IPD model also eliminates the need for overtime labor and lowers spending on general conditions, insurance, and carrying expenses.

Close-out Paperwork to continue using the documents from the design and construction phase through to facilities management and overall building lifecycle management, the project owner/operator must migrate to a BIM-centric approach for all project documents, which converts the traditional close-out documents into digital ones.

22 Data Is the Core Value of BIM

During the construction phase, BIM can be a key factor in enhancing the project's data stream. A BIM model, however, is only as good as the data that is supplied to it. The assertion that data is the core value of BIM, and that digital adoption is essential to a project's success is thus not hyperbole. [14]

Figure 29. BIM data. Source: logikalprojects.com

In order to standardize the construction process and provide outcomes that can be reliably repeated in the future, data is a crucial component. When creating onsite quality processes across teams and enhancing the projects' as-built documentation, for example, the ability to integrate quality and compliance processes to the BIM model can be very helpful. It is also crucial to outline a specific set of internal classifications. Lack of a formal protocol for on-site follow up is a persistent problem for many businesses. Health and safety as well as quality control may suffer significantly as a result.

Stakeholders can ensure that procedures are standardized and automated to reduce the workload on site by mapping object classes to specific planned tasks, checklists, forms, and teams. Field data travels back to the model once every task has been finished and has been verified beforehand. It is clear that getting BIM into the hands of the field personnel is the construction industry's biggest difficulty. Every organization needs user-friendly digital solutions that will enable onsite staff to submit updates directly from the job site and keep the BIM model up to date in order to accomplish this.

After all, the kinds of information that field workers and BIM management require are very different. For workers, a modern 2D representation can be perfectly enough because it enables them to concentrate solely on the data they need. This clarity can eliminate ambiguity from the progress reporting procedure and encourage individuals to digitize their everyday work routine. The first step towards a unified data environment where all project agents stay on the same page and share critical information in real time is unquestionably increasing digital adoption. [14]

In order to communicate better, gather more data, and rebuild confidence among the various project teams, project teams can easily organize their systems and procedures in a data-driven environment. [14]

23 BIM Lifecycle Improvement:

BIM performance improvement involves a number of processes, each of which has a six-phase lifecycle that begins with the identification of needs, evaluation of current capabilities, and analysis of data gathered. A thorough planning phase that results in the measures required to increase performance comes next. Achievements are assessed at the conclusion of each phase and used to develop plans and provide information for the following performance improvement cycle.

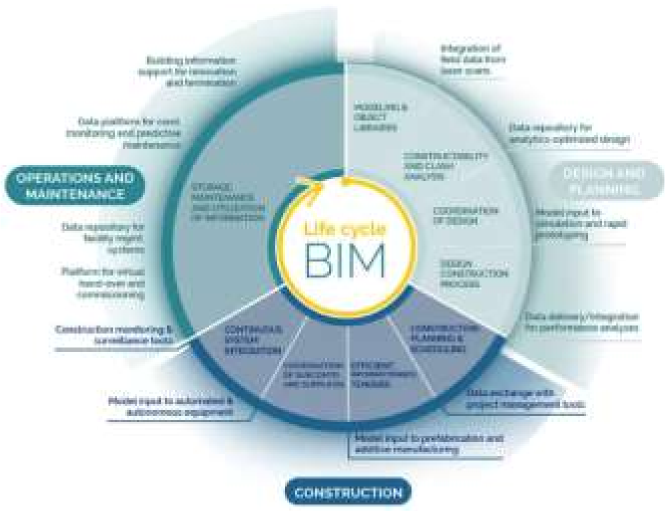


Figure 30. BIM Lifecycle. Source: cemexventures

23.1 Scoping documents

Define the vision, identify metrics, and generate timeline

23.2 Results & Charts

Discover or evaluate proficiency, generate results

23.3 Analysis report

Collate results, analyse findings, and generate a detailed report

23.4 Action plans

Create goals, pinpoint gaps, and create action plans (BIM Project Execution Plan)

23.5 Tracking logs

The Document Management Module's Activity log gives a chronological account of project activities. Each activity is noted down along with the date, time, user, and action.

24 Common Data Environment Concept

All sophisticated BIM applications may export data in open-source common file formats as CoBie or IFC (Industry Foundation Class). (construction operation building information). Consider a sizable construction project that includes numerous stakeholders from various nations using various BIM software applications. They won't have to lose data or rebuild the building because they can share the building information saved in a common data environment using the IFC file format. A team using Autodesk Revit may transfer the file to a team using Vector Works, Tekl, or any other BIM software. Therefore, using the BIM process in a project does not require all parties involved to utilize the same piece of software; rather, we can export our building information to an open-source file format like IFC.

25 Implement BIM in 7 Steps

25.1 Gain Executive Support

BIM adoption at a company is not a straightforward process. Therefore, you must make sure that the team and all other project stakeholders are on board. The choice to switch to BIM is a complex procedure. But in the long run, these expenses pale in comparison to the advantages of a full, integrated system. [15]

The adoption of new technologies may also require some kind of organizational change management. For instance, a company could need to hire a BIM manager to ease the transition. Many project managers and executives have disregarded BIM in the past as a costly, time-consuming procedure that would interfere with their already hectic workflows and schedules. [15]

These worries can, however, be easily outweighed by the usefulness and advantages of BIM. It frequently starts with something as basic as your senior's lack of understanding. In this situation, it would be beneficial to spend some time outlining the widespread adoption of the new methodology and outlining the benefits that come with it in order to increase the likelihood that they will accept it. [15]

Aligning BIM implementation with company goals is another strategy to raise the likelihood that they will give it some thought. When you obtain high-level assistance, you can go on to the following step.

25.2 Develop a Plan

The main tools required to implement any new procedure or project are strategy and planning. It is a good idea to design a structured BIM Implementation Plan because of this (BIP). This document would specify everyone's responsibilities as well as the objectives and specifications. Another thing to keep in mind is that your company will need time to adapt to BIM because it is a new procedure. Undoubtedly, initiatives don't always go as expected. As a result, reviewing and changing your goals is a process that you must go through to keep your company on track.

25.3 Choose Software

You should conduct some study before selecting the BIM program. Make sure you are knowledgeable about all the features that are offered so that you can select the best program for your requirements. These include scheduling and planning, budgeting, cost prediction, and efficiency enhancement, among other things.

The quality of the software you use should be one of your top priorities. It's crucial to confirm that the program will meet all your needs and potential workflows. It can be difficult to decide. As a result, before making a purchase, we advise checking out several software programs. To allow you to try out its features, several offer free trials. You can then decide if it would be beneficial for your business.

As an alternative, if you locate software that suits your needs, you can ask for a walk-through of the procedures to better comprehend them.

25.4 Set Goals

Setting strategic goals can assist your team in staying on course and having a clear understanding of your aims. These objectives must be clear, quantifiable, doable, practical, and time-bound. Determining success and what it means for the company will be one of these objectives.

BIM software can be helpful for tracking your progress and staying on track with your objectives.

25.5 Choose A Team

It's crucial to specify each position on the project team when creating the team for your BIM project. By doing this, everyone will be aware of what is expected of them.

In order to promote a favourable adoption of the new software and workflows, the team chemistry is also essential. Team members must be willing to share their experiences and learn from one another. Facilitating open learning sessions would be a smart move to support such an atmosphere. [15]

There should be some sort of communication with every employee as a precaution to guarantee higher organizational support. As an illustration, BIM Spot provides multiple model checks in the cloud to prevent any conflicts while you plan. Everything is kept current with the project's progress thanks to this.

25.6 Train Employees

When implementing new software, the project manager must make sure that their team receives the necessary training to use it. It can take some time because certain employees might find it difficult to adjust. However, the process can be streamlined with carefully prepared sessions. [15]

In order to implement the knowledge immediately after learning the fundamentals, it also makes sense to start a first pilot project right away. As the project moves forward, expertise should be enhanced through online webinars and tutorials, which are effective and cost-effective because there is a wealth of content available online. [15]

25.7 Monitor, Evaluate, and Adjust

After you have deployed BIM, your attention should then shift to streamlining your procedures. This calls for constant observation, assessment, adjustment, and repetition.

You will get more knowledge and be able to improve your projects as you use the software. Additionally, you may enhance the quality of your projects by going back and reviewing various phases as you go along and making the necessary improvements. [15]

26 BIM Standards

Building information modelling is described as "a digital representation of physical and functional aspects of a facility" in the definition of a BIM standard. A BIM, which is described as existing from the earliest conception through demolition, is a shared knowledge resource for information about a facility that provides a reliable basis for choices throughout its life cycle. Everyone is curious about what BIM can accomplish for construction and building expositions at the moment because it is causing a lot of buzz in the construction sector. BIM technologies and concepts have a 50-year history and are constantly developing today. [16]

More creative solutions are introduced as these technologies advance. By connecting buildings, as object-based models, to a database, BIM technologies enable the representation of the inherent and physical attributes of every building.

By enhancing the program environment and classification with particular features, modern BIM can increase the representation capabilities of engines and greatly increase the efficiency of the construction of model components.

Whenever a change is made to the model while the project is still in the planning stages, all changes and project drawings are updated to reflect the changes.

First BIM standards around the world:

The International Organization for Standardization has released the first worldwide BIM standards (ISO). These new requirements include:

- Part 1: Concepts and Principles
- Part 2: The asset's delivery phase

These are the new ISO 19650 standards, and they deal with the digitization and management of data regarding buildings and civil engineering projects, including BIM. Based on two British standards are the following

- BS 1192

Public standards

- PAS 1192-1
- PAS 1192-2.

All standards made a considerable reduction in user construction costs. These new international standards, according to ISO, are intended to provide a more useful framework to aid designers and contractors by improving all phases of construction through more effective collaboration. [16]

26.1 BS 1192 – Collaborative Production of Construction, Engineering, And Architectural Information.

The first information management standard, BS 1192, outlines industry norms and recommendations for the cooperative development of information (aka BIM).

This is largely based on the standards, practices, and protocols created during the construction of Heathrow Terminal 5. And is still the only standard that has undergone extensive project testing.

The common data environment (CDE) and the transactions across container states within the CDE are the main topics of this paper. Additionally, it includes the standard codes for fields as well as the naming rules for the CDE's containers (folders, files, and layers).

BS 1192 includes:

BS EN ISO 9001 – Quality management

Requirements:

- BS EN ISO 13567-1 – CAD overview and principles
- BS EN ISO 13567-2 – CAD Codes and formats used in construction documentation
- ISO 12006-2 – Framework for classification information in construction works
- BS 7000-4 – Design management systems

- BS 8541-2 – Recommended 2D symbols of building elements for use in BIM

26.2 PAS 1192-2

The basis for cooperative working and information management in a BIM Level 2 environment is provided by PAS 1192-2. The British Standards Institution, Mark Bew MBE, and Mervyn Richards OBE own the copyright of PAS 1192-2:2013. Regardless of the method of procurement or the type of contract employed, the creation of coordinated design and construction information is a task- and time-based process. For the advantage of everyone engaged, each task must be completed in a specific order known as "collaborative functioning."

Accurate, partial, and confusing information can increase capital delivery costs by 20–25%. Teams must produce information in a collaborative setting utilizing established standards, procedures, and processes to ensure consistency and quality, enabling reuse and repurposing of information without modification or interpretation. In a collaborative working environment, it is unacceptable for a participant to insist on "my standards.". Collaboration will be hampered if an individual, office, or team changes the process without consent. Since the production of this information has always been necessary, this strategy does not add to the workload. If the information is to be created and delivered consistently and on time, truly collaborative working necessitates mutual understanding and confidence within the team as well as a deeper level of standardised process than has previously been observed. Working in this manner may result in fewer delays and team disagreements, improved project risk management, and a better awareness of where costs are being incurred. Lean principles should be used whenever possible to minimize resource spending for any objective other than the production of value for the employer. Understanding the information's intended purpose is essential for really lean information generation. To ensure that information may be used and reused throughout the project and life of the asset, this is accomplished by "starting with the end in mind" and identifying the downstream uses of information.

It is believed that PAS 1192-2 will be equally valuable to large multinational corporations and small practitioners. All initiatives could be affected equally by waste and bad information management. Where appropriate, we have included guidance on how to scale up the methodology and process outlined here to work for all organizations. Starting from the end in mind. By 2016, the UK Government Construction Strategy hopes to cut the price of assets for the public sector by up to 20%. In order to ensure that the government always gets a fair deal and that the country gets the long-term social and economic infrastructure it needs, the plan asks for "a fundamental shift in how public authorities interact with the construction sector.". Although fundamental issues with acquiring public assets have been well-known for more than a century, little has been done to address them thus far. The Construction Strategy outlines a variety of tactical goals that taken together will solve these issues. Construction information modelling (BIM) maturity Level 2 has been designated as a specific strategic goal for all public sector asset procurement, with equal application to private sector building, infrastructure, refurbishment, and new-build projects. This will deal with the issue of erroneous, insufficient, and unclear information, which causes unneeded additional capital delivery costs of 20–25%. The introduction of Computer Aided Design (CAD) solutions was thought to have the ability to increase information consistency, but at best it has only contributed to exacerbating the issue The standards, practices, and procedures defined in BS 1192:2007 and this document can help decrease the additional 20–25% waste that is currently present in the industry. Throughout the lifecycle of a building, a facility, or an asset, BIM creates information models and the information that goes with them. The above B1M video depicts the information delivery and project management cycle, which depicts in blue the general process of determining a project need (which could be for design services, construction, or the supply of goods), obtaining and awarding a contract, mobilizing a supplier, and generating production information and asset information pertinent to the need. Every part of a project, including the improvement of design knowledge through the seven project stages depicted, follows this cycle in green. The "shared data environment" information delivery process is represented by the green parts.

To support the planned preventative maintenance program and the portfolio management activities for the asset's lifetime, PAS 1192-3 provides recommendations on how to utilize and maintain the asset information model (AIM).

For the information management requirements related to projects provided using BIM, PAS 1192-2 offers detailed guidance. Not every piece of project information will be created, shared, or managed in a BIM format. In order to facilitate accurate and efficient information transmission, this information will also need to be managed in a consistent and systematic manner. The standards and procedures that ought to be used to produce these results are described in detail in BS 1192:2007. Only information flows relevant to BIM are described in PAS 1192-2.

27 Standardisation Efforts

The construction industry is governed by a plethora of standards, rules, codes of practice, and laws, just like many other manufacturing industries. Construction projects are safer because to these facilitators and restraints, which also aim to boost success rates. Additionally, they enable and align stakeholder expectations of project achievements, represent and communicate a shared understanding of the pertinent principles applicable to our initiatives, and work toward achieving global equality across cultures, time, and space. The application of standards ensures societal advancement and well-being, regardless of the material strength and suitability, calculation method, quality levels, practice methodology, or outcomes. They are essential for stakeholder communication in transitory project organizations operating in a fragmented industry. Building a community around a standard with an implicit script that unites people and things in a world already crowded with conflicting norms and standards is known as standardization. The sector culture has a tendency to prioritize process optimization at the individual or organizational level rather than overall (since nobody owns in the whole process in construction). Therefore, in a BIM context, it is crucial to classify and comprehend the strategic distinction between branch or sector standards and organization standards (which may even be trade secrets). We may learn from the ICT domain's expertise when we consider BIM as an end-to-end delivery methodology because there are many parallels between the two fields. ICT standards are typically broken down into three categories: concepts, data models, and processes. For everyone to speak the same language, common concepts and categories for concepts are required. Systems and players must be able to share information intelligibly, hence neutral data model formats are necessary. Finally, a standard information distribution process and a shared working approach are required. We can arrange BIM standards themes around these 3 divisions. [17]

- CEN TC442 BIM: Standardization in the field of structured semantic life-cycle information for the built environment.
- CEN TC287 GIS: standardization in the field of digital geographic information for Europe.
- ISO/TC211 GIS: Standardization in the field of digital geographic information.
- ISO/TC59/SC13 BIM: Organization of information about construction works.
- ISO/TC184/SC4 STEP: Standards that describe and manage industrial product data throughout the life of the product.

- Open Geospatial Consortium: International not for profit organization committed to making quality open standards for the global geospatial community.
- building SMART: International organization which aims to improve the exchange of information between software applications used in the construction industry.
- EU BIM Task Group: It's aim is to bring together national efforts into a common and aligned European approach to develop a world-class digital construction Sector. [17]

28 Interoperability and Data Exchange in BIM

The building environment industry has benefited greatly from the development of building information modelling. Because it makes it possible for us to compile all project data into a single model. However, not all the data is pertinent to every project participant. It's crucial to have access to the necessary building data and be able to interpret the BIM model's data correctly. Because of this, a BIM model needs ongoing management and upkeep. Huge amounts of data are transferred between numerous stakeholders and multiple expert groups throughout a large BIM project. Within each professional team and between specialties, there is a lot of communication and file sharing. Each group has a certain level of access to the data in the central model, also known as work share in the BIM model. Interoperability is the ability of numerous software programs to work together seamlessly by using structured data and sharing the same categories and logics. [18]

Figure 31. Introperability. Source: cybrreality

The Oxford Dictionary defines interoperability as the capacity of computer systems or software to share and utilize data. When several disciplines are engaged in the creation of building information and papers, software interoperability helps projects run more efficiently and saves time. software program that is extensively used in the field. [18]

One of the reasons why this organization has been so successful in luring many professionals in the design, engineering, building, and operation is the robust interoperability between different Autodesk programs. [19]

28.1 Open-source File Formats

These days, many software programs import and export files from other software programs using open-source file formats.

One of the most significant open-source file formats in the realm of BIM, IFC (Industry foundation classes), was developed through forging clever international alliances. Any other BIM program can import the data that was extracted from the BIM model as an IFC file.

28.2 CAD Data Exchange File Open Source

As an open-source alternative to DWG, DXF files can be used in a variety of software programs.

28.3 Data Extraction

Various types of building information and data can be extracted from a BIM model.

28.3.1 Autodesk REVIT as an Example

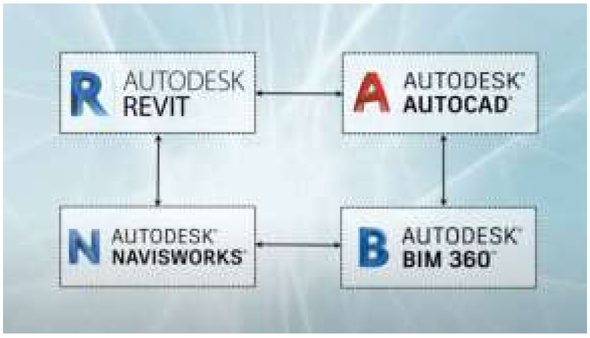


Figure 32. Autodesk REVIT. Source: cybrreality

Revit models may export to a variety of CD formats, including DWG, dxf, dgn, and acis. These file types may be read using free software like Autodesk design review and do not require the installation of resource-intensive Autodesk apps, such as DWF and DWFX compressed cad files that can be simply shared for additional reviews. Usually used for final rendering for the production of games and media, the Fbx file format connects Revit files with 3d Studio Max. For the creation of 4D simulations and the insertion of time dimension into building projects, NWC files can be readily loaded into Navisworks. NAB models can be saved in an open-source format called IFC, as was already indicated. IFC file types are supported by 14 different Autodesk software products, including Revit. Leading BIM products including Autodesk, Trimble, Graphisoft, and Bentley all support the GBXML file format. It makes it easier for building data to be transferred from BIM models to engineering and building energy analysis systems. [19]

Figure 33. BIM IFC. Source cybrreality

It is simple to convert a BIM model into an energy analytics model and save it as a gbxml file. With the help of this file format, reports can be extracted from the Revit model and advanced building energy analysis and performance tools like design builder may also be used. Additionally, the model can be exported as still files for usage in 3D printing devices by installing the STL plugin on Autodesk Revit. The interoperability and capabilities of BIM tools will expand with the addition of more 4 plugins. Format plugin, for instance, can be used to produce 3D objects, PDF files, and much more. [18]

In conclusion, even though we put a lot of time and effort into building a thorough BIM model, we should also work to enhance our data extraction and model documentation. [18]

29 BIM Maturity Level- Levels 0,1, 2, and 3

Searching for BIM jobs in the sector Some positions as a BIM coordinator or BIM manager require BIM level 2. Building Information Modelling standards, which are widely accepted in the building sector, include BIM majority levels. The BIM dimensions and maturity levels are related. Although not the same, these two terms are closely related. BIM maturity refers to the amount and quality of data that a BIM model contains, as well as the various BIM dimensions used in a project that are shared among and maintained by various stakeholders. Mark Bew and Mevin Richards were the ones who initially mentioned the BIM maturity level. [20]

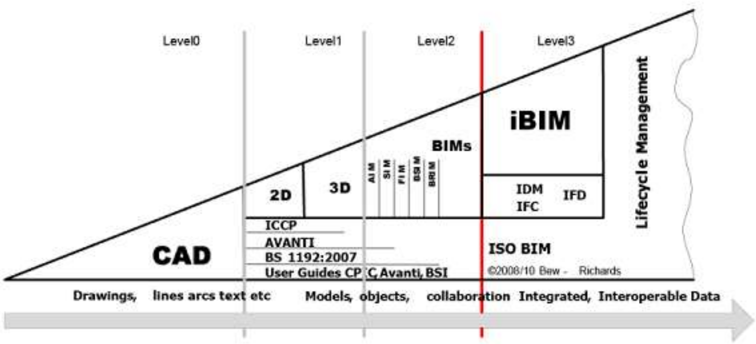


Figure 34. BIM Maturity Levels. source: https://biblus.accasoftware.com/

29.1 Richness and Level of Data BIM Dimensions

The depth and quality of the data integrated into the BIM model grows. The BIM process now includes more aspects of time, cost, and other factors, and there is increased cooperation between many stakeholders.

The sort of level and depth of participation in a project are also related to BIM maturity.

29.2 Level zero (0) BIM

The application of CAD drafting methods in a project is level zero BIM. Since there is no cooperation between the many stakeholders, it is hardly a BIM process. Therefore, there is no collaboration in a straightforward 2D drawing similar to CAD drafting.

29.3 Level (1) BIM

Using digital tools to create 2D and 3D architectural and construction drawings is referred to as level one BIM. It involves sharing files and data through a CDE, or common data environment. Collaboration between disciplines at level one BIM is non-existent or minimal. Level One BIM is therefore about

- 2 dimension and 3dimension drawing

- Advanced file-sharing strategies
- No or partial collaboration between different disciplines

29.4 Level (2) BIM

Based on UK 1192, a set of national standards and publicly available specifications in the UK, the BIM 2nd level concept entered the UK government standards in 2011. For projects receiving public funding, Level 2 BIM is required. In Level 2 BIM, time and cost are added as the fourth and fifth BIM dimensions, respectively, and data is produced and manipulated in addition to 2D and 3D. Working cooperatively with various stakeholders is a level 2BIM procedure. Advanced, file sharing, interoperability, and common file types are all included.

Level 2 BIM is where you'll mostly see terminology like "BIM protocols," "BIM execution plan," "model federation," and "shared data environment."

29.5 Level (3) BIM

In the world of BIM, Level 3 is a relatively new idea. Although it has been extensively discussed in academic and research circles, the building industry has not yet defined it. The complete collaboration is achieved utilizing a solitary central shared model that houses all building information and is accessible to all project participants. The interferences between the many disciplines in the construction project are minimized and the coordination between them is increased by this idea, also known as open BIM. Level 3 BIM displays the BIM dimensions above 5D, as was indicated in the preceding chapters.

Energy use and sustainability are extrapolated in the sixth dimension of BIM. We can evaluate our building using 6D in comparison to several energy rating systems.

7D focuses on facilities management, a building's life cycle analysis, and building maintenance. Building safety is explored in the eight BIM dimension. It combines emergency preparations, building security, and safety measures.

Therefore, despite the names being different, there is a relationship between BIM dimension and BIM maturity levels.

30 Integrated BIM (IBIM)

In fact, the third generation Building Information Model (BIM) is very intriguing. Having a single building that contains all of the building's information makes it easier for us to comprehend and manage a building throughout its life cycle. It also brings us one step closer to the provision of smart services, welcomes the incorporation of real-time data, and encourages the creation of a digital twin of the building.

To sum up, BIM maturity refers to the depth and type of collaboration in a BIM project, as well as the richness and amount of data.

31 Scan to BIM

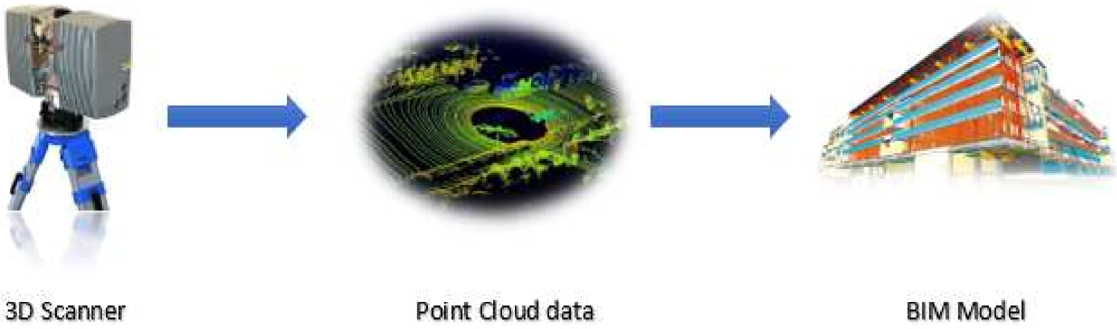


Figure 35. Scan to BIM. Source. Autodesk

Scan to BIM is the process of accurately digitizing a physical place using 3D laser scanners for use in the Building Information Modelling process. To obtain the building's as-built information, it is possible to scan both the inside and exterior of the structure. It is obvious that the majority of construction industry experts, including planners, civil engineers, architects, architectural technologies, BIM coordinators, surveyors, etc., greatly benefit from this technology. [19]

Reality capture is yet another word associated with scan to BIM that is really helpful.

With the aid of digital technology called reality capture, users can turn photos or laser scans of a structure or environment into 3D models. Reality capture can produce extremely accurate and comprehensive 3D models that can be used in BIM-enabled projects. [21]

31.1 Laser Scanner

Some advanced laser scanners work with Lidar technology was made officially accessible in the 1990s.

31.2 Lidar Technology

For light detection and range, use the term "Lidar." For many years, this technology has been employed for a variety of surveying tasks. It has uses in mining, autonomous vehicles, robotics, agriculture, geology, archaeology, and of course construction. Initially developed in the 1960s, lidar technology initially appeared in a number of reputable scientific journals in the 1980s. Lidar technology was made commercially available in the 1990s for use in engineering and design. The use of Lidar technology in the construction industry greatly improved between 2016 and 2018. With a straightforward explanation, a laser scanner sends out amplified light that hits an object; the gadget then determines the object's location by timing the light's return. The positions of all the objects will be recorded point by point by positioning a laser scanner in the centre of the area. These points are combined to produce a point cloud of data from space. We can accurately model an object or a space using the point cloud data. The need for laser scanning in the construction industry is steadily rising, according to data published in the Autodesk construction blog. This is because this technology is so accurate. the efficiency of the laser scanning process, the projects' financial viability, and its applicability to and interoperability with BIM tools, procedures, and workflows. Throughout the many phases of a building's existence, laser scanning has a variety of uses. It aids projects in enhancing the precision of site surveys and the inclusion of accurate site elements during the planning and design phases. The use of laser scanning during and after the construction stage enhances coordination between many disciplines and systems, such as mechanical and electrical. Because it creates a precise as-built model of the building, which makes all repair and retrofitting operations easier, laser scanning is particularly helpful for the maintenance and demolition phases of a building's life cycle. [19]

31.3 Challenges:

Applications of laser scanners in building projects have some downsides and disadvantages, just like any other cutting-edge technology.

1 - Initial price

Costly laser scanners, particularly the most precise ones, are sometimes necessary. Like with any other digital technology, you should compare the laser scanner's characteristics with your needs before making a purchase. we may want to think about renting a laser scanner first to reduce the cost risk. [18]

Despite the initial high cost, buying a laser scanner might be very cost-effective in the long run depending on the type of construction company you work with.

2. Training

The training requirements for 3D laser scanners are their second disadvantage. To take advantage of it, just as with any other technology, you must learn how to use the hardware and software. It's not challenging or complicated to use a laser scanner to scan a space. Cleaning and utilizing the collected point cloud data is typically the difficult part. Additionally, free training is typically provided when purchasing a laser scanner. But generally speaking, training costs time and money. The process of integrating the collected point cloud data into a BIM application is called "scan to BIM," and there are some excellent step-by-step instructions online. [18]

3- Transformation

We need to adopt new technology and take initial risks in order to overcome the various problems of doing so, such as the modifications and transformations that new technologies like a 3D laser scanner make to your present processes. In order to record planning and adjustments in accordance with other technological processes in the project, it is always advisable to begin introducing a new technology at the beginning of the project or a distinctive stage of the project. [18]

When we obtain the point cloud data from the laser, we can use Autodesk Revit or Civil 3D to alter the scan file data by importing and converting it to the RCP point cloud format using the software Autodesk Recap Pro. [18]

32 The Case Studies

32.1 Introduction

The mechanical, electrical, and plumbing (MEP) components of a facility can account for up to 60% of its overall cost in the construction business. Dealing with the expense of MEP on construction sites becomes a top issue when the time and quantity are considered, along with the difficulties in routing each of its systems. This procedure is typically thought of as a time-consuming addition (4dimension) to calculating to identify the cost (5 dimension) of the MEP systems. These techniques got quicker and supplanted the conventional method as a result of the development of various applications. Beyond that program, BIM technology introduced new procedures for estimating with incredibly detailed visuals. BIM technologies are still being debated as the optimal method for MEP quantity take off, nevertheless. By utilizing BIM technologies in four and five dimensions, the goal of these case studies is to gain a better knowledge of how BIM systems may improve MEP estimation. In the first case study the time or four dimensions will be under examination for the BIM systems and for the second case study the cos (five dimension) will be examined in the real projects.

33 Case study Number One

33.1 The Objective of the Thesis

The subject of the case study called, "reconstruction of the UNIPOLSI complex towers in Turin city" which is located in Corso Galileo Galilei,12 (Turin) near the PO river which was built in the mid-1960s according to a design by architect Amedeo Albertini.

Figure 36. project on the MAP. Source: Google map

The analysis of the design of the procedures that follow was made possible thanks to the collaboration of professional technical firm Prodim S.r.l company.

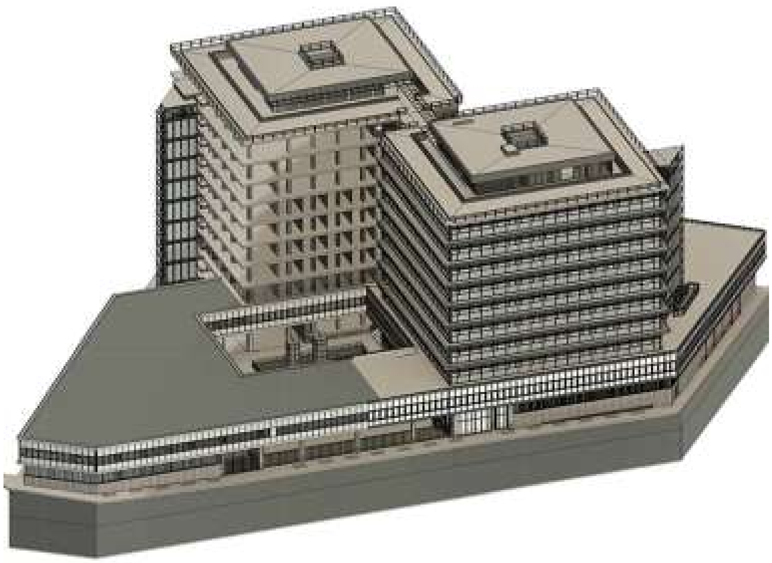


Figure 37. 3D picture of project. source: Tecnopolis

This is the integral design of an intervention on the new, consequently, it represents, given the nature of innovation for the client, a pilot project for the application of a full-BIM methodology. in fact, the entire process was managed. As the title, this is an intervention that involves the implementation of the interregional. What is about to be reported is taken from the Illustrative Technical Report by the Prodim s.r.l consulting engineer company which is responsible for the HVAC system design as well as my personal examination through the BIM systems using the different software such as REVIT and NAVISWORKS.

33.2 Key Plant of the Project

The project contains of five main bodies tower A, tower B, body C, body D, and body E presented as five zones for estimating the thermal and cooling loads for designing the HVAC systems. As the main purpose of this structure is to be applied offices so most of the spaces are single offices, meeting rooms and offices in the open spaces. Also, there are other areas and facilities are considered such as clinic, library, museum, break rooms, dining room restaurants, meal distribution, kitchens, scullery, printer room, electrical rooms, storage rooms, closet rooms, local warehouse room, dressing rooms, bath rooms, restrooms, and showers.

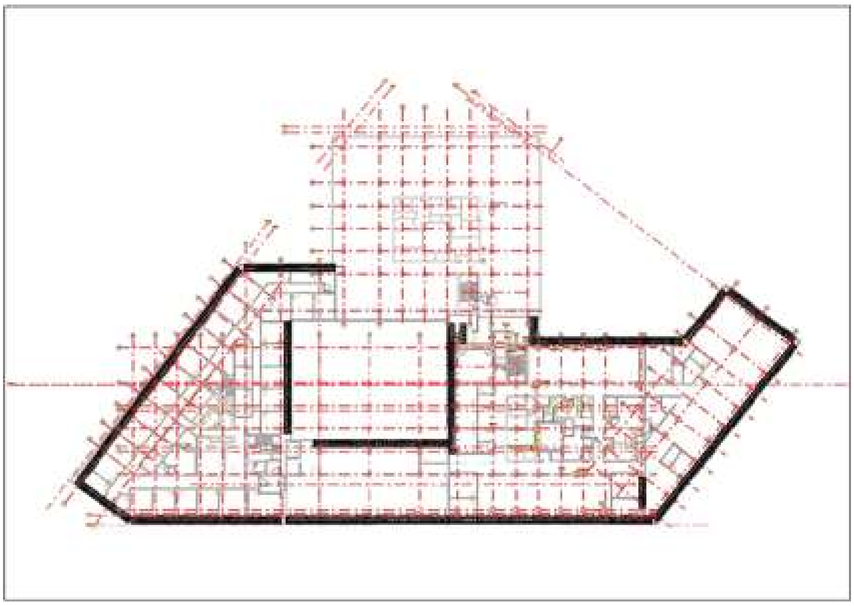


Figure 38. AutoCAD scheme of the project. Source: Prodim document

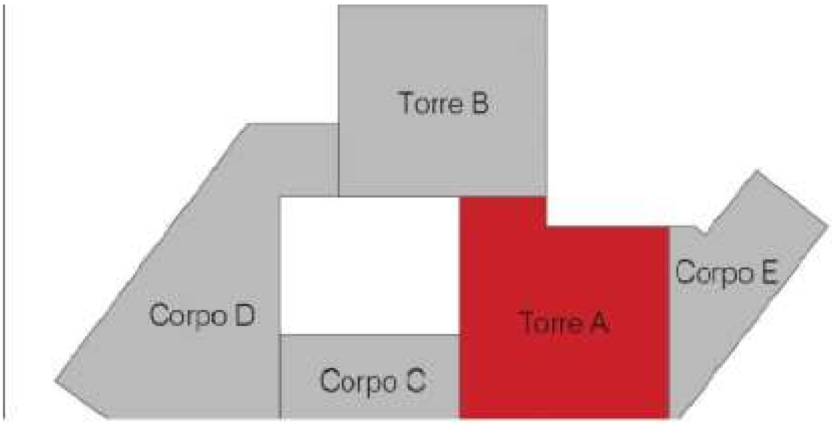


Figure 39: Key plant of project, source. Prodim document

33.3 HVAC Design Method of the Project

The choice of system is influenced by three key elements: the design of the structure, the climate, and the preferences of the owner. To achieve the goal and please the building owner, the design engineer is responsible for taking into account numerous systems and recommending more than one system. Climate change (e.g., temperature, humidity, and space pressure), building capacity, spatial requirements, economic factors including capital cost, operating cost, and maintenance cost, life cycle analysis, reliability, and adaptability are a few factors that can be considered.

However, there are several restrictions that must be identified while choosing a system. These limitations include the building's configuration, the space that is available, the construction budget, the available utility source, and the building's heating and cooling loads.

In this project, the climate control systems use the constant air volume (CAV) technology, which offers a constant level of airflow temperature and upholds a constant air pressure throughout the system. For CAV systems, a building typically needs two sets of ductworks: one for supply air and one for return air that is connected to the AHU (Air Handling Units). To quickly regulate the interior temperature, these air supplies are either delivered by separate air handling units or a single central unit known as a CAV box.

As it can be seen in the figure 40, The air handling units' duct work such containing supply, return, fresh and exhaust air, the pipeline for the duct, and even ductwork of the project, as well as the CAV system which, are done with REVIT software to be used in BIM systems.

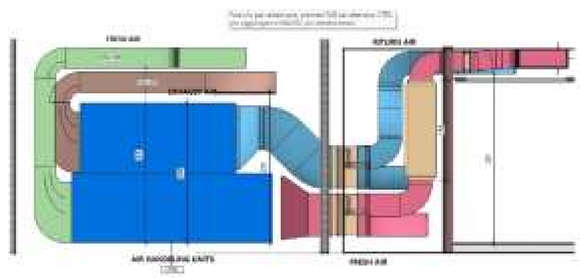


Figure 40. Air Handling Units Duct Work. Source: Prodim Document

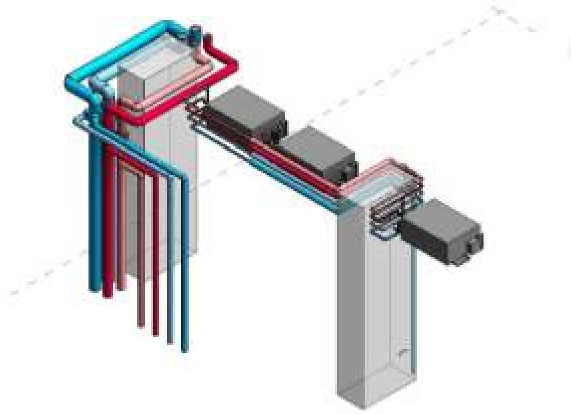


Figure 41. Piping Line Of Fan Coils. Source: Prodim Document

Figure 42. Fan Coils, Duct Work, And Cav Systems of the Project Source: Prodim Document

33.4 Technical HVAC Design of the Project

The HVAC method design which is used in this project is Cooling Load Temperature Difference (CLTD) which is the initial step in air conditioning is cooling load estimate. According to the ASHRAE 1997 principles, the CLTD approach is the most useful method. This technique can only be used for plane data, which makes it simpler to automate using computer software. Consideration of the outside and indoor design environments is the CLTD's standard operating practice.

As it has shown from the figure 42 the internal condition temperature design is 26c° for the cooling load and 20c° for the thermal load and 50 percent humidity is chosen is for both thermal and cooling load calculation. Moreover, the occupation percentage has been taken into account according to the UNI 10339 standard as well as fresh air for internal spaces.

Figure 43. Thermo-hygrometric conditions of air-conditioned areas. source. Prodim Document

33.5 Standards Employed

-Calculation of energy requirement UNI EN ISO 13790:2008

-Determination of the thermal energy demand of the building for summer and winter air conditioning UNI/TS 11300-1:2014

-Determination of primary energy needs and efficiencies for winter air conditioning, domestic hot water production, ventilation, and lighting in nonpresidential buildings UNI/TS 11300-2:2014

-Determination of primary energy needs and efficiencies for summer air conditioning UNI/TS 11300-3:2010

-Energy performance of the building- calculation of primary energy and the share of energy from renewable sources UNI/TS 11300-5:2016

-Building components and elements – thermal resistance and thermal transmittance UNI EN ISO 6946:2007

-Energy exchange between ground and building UNI EN ISO 13370:2008

-Thermal bridges in buildings – lineal transmission coefficient UNI EN ISO 14683:2008

-Transmission and ventilation loss coefficient UNI EN ISO 13789:2008

-Hydrothermal performance of building components and elements – temperature internal surface to avoid critical surface moisture and condensation interstitial – calculation method UNI EN ISO 13788:2003

-Thermal performance of building components – thermal characteristics dynamics – calculation UNI EN ISO 13786:2008

-Thermal transmittance of glazed components UNI EN ISO 10077

-Heating and cooling of the building – climatic data – monthly averages for the assessment of the thermal-energy performance of the building and methods for distributing solar irradiance into the direct and diffuse fraction and to calculate the irradiance on sloping surface UNI 10349-1:2016

-Thermal conductivity and vapour permeability of building UNI 10351

-Brick and floors thermal resistance values and calculation method UNI 10355

33.6 Standard UNI 10339 as an Example

Aeraulic air-conditioning systems - Classification, prescriptions, and performance requirements for design and supply.

Figure 45. UNI 10339 standard. Source: biblus.acca

The standard's goal is to correctly identify the ambient conditions and plant traits necessary to provide the specified levels of comfort and health protection for people. The goal of the standard is to increase the energy performance of the building-plant system through cost-effective interventions without sacrificing thermohydrometric comfort or air quality, in addition to safeguarding people's health and comfort. As a result, it connects to UNI EN 15251 and UNI EN 13779 standards, constituting their essential national implementation and contextualization. The standard is applicable to all hydraulic systems installed in residential and nonpresidential buildings for the purpose of controlling indoor temperatures, humidity levels, air quality, and air movement.

The following remain excluded from the scope of this standard:

- Winter heating and/or summer cooling systems in buildings without ventilation mechanical/hybrid ventilation.

- Systems intended for other purposes, such as those for the storage of products

- Consumable products or for creating conditions suitable for particular industrial processing (plants process);

- Installations intended for rooms in which the presence of smokers is permitted, for which reference is made to the UNI XXXXX standard

- The systems for winter air conditioning of buildings used for industrial and craft activities for which reference is made to UNI 8852.

33.7 Explanation of the Complex Building of the First Case Study

The complex building which will be the first case study is included towers A, body C, D, and E. Tower A is built on ten flowers and two basements. The grand floor, first, and second floors, and basements are joined to the bodies C, D, E. as can be seen in the figure which is the section of the complex building

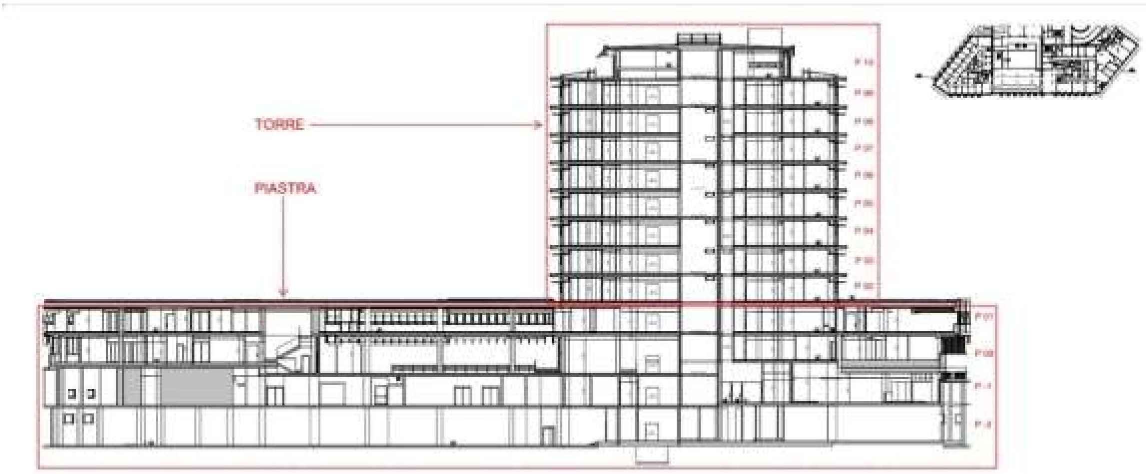


Figure 46. Building section. Source: Prodim Documents

As it is required to calculate the thermal load and coaling load which is essential to design and draw the air conditioning systems for more forth use all calculations will be seen as follows. figure number 48 which is a calculation of the grand floor of tower The areas(around15000m^2) of the building and the calculation of thermal load and cooling load kw for the building and figure number 48 it is the result for the whole project.

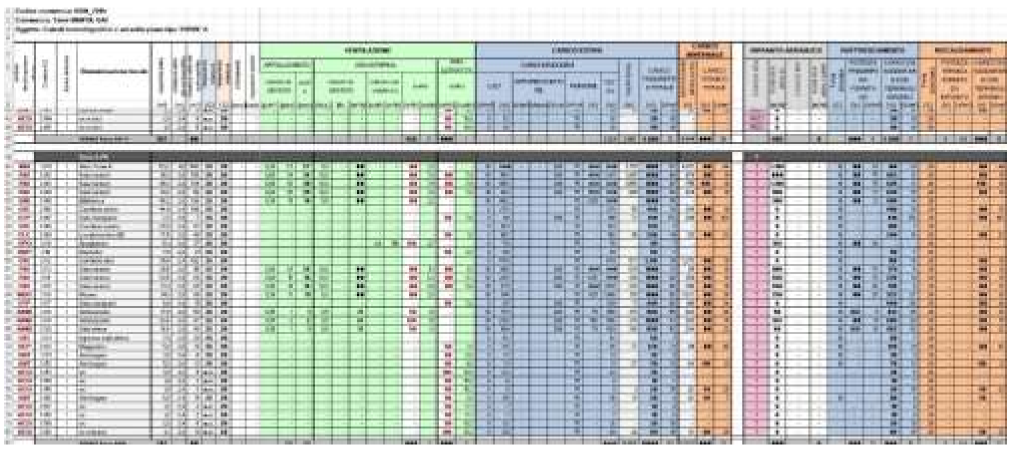


Figure 47. Calculation of Thermal Load Tower A. Source: Prodim Documents

	Superficie netta	Persone TOT	Aria esterna	Aria estratta	Carico raffrescamento	Carico raffrescamento
	[m^2]	[-]	[m^3/h]	[m^3/h]	[kW]	[kW]
Torre A	8.710	1.380	54.950	35.200	352.913	237.970
Torre B	791	0	2.800	3.200	2.355	14.090
Corpo C	548	44	2.400	1.050	15.220	25.690
Corpo D	2.484	215	12.000	7.650	65.593	74.670
Corpo E	1.781	405	26.450	3.650	29.498	35.860

Figure 48. Thermal and Cooling Load of the Building. Source: Prodim documents

33.8 Normative References for the BIM System

With regard to the Information Management Offer and its contents, reference is made to the UNI 11337 standard, in particular:

Part 1: Models, outputs, and information objects for products and processes;

Part 2: Naming and classification criteria for models, products, and processes;

Part 3: Models for collecting, organizing, and storing technical information for construction products. (Digital information sheets for products and processes);

Part 4: Evolution and information development of models, products, and objects.

Part 5: Information flows in digitized processes.

Part 6: Guideline for drafting information specifications.

Part 7: Knowledge, skill, and competence requirements for figures involved in the digital management of processes Information.

Other normative references in relation to specific topics can be found in the table below:

Table 2		applictions							
		REFERENCES	INFORMATION FLOWS	FLOWS OR DATA	FILE NAMING	OBJECT NAMING	LOD	ACDat	OPEN FORMATS
standards	BS 1192:2007				X			X	
	PAS 1192-2:2013	X							
	PAS 1192-3:2014	X							
	UNI 11337:2017 PART 4			X			X		
	UNI 11337:2017 PART 5		X						
	UNI 11337:2017 PART 6	X							
	for project				X	X			
	omniclass table 23					X			
	uni EN ISO 16739								X

Figure 49. Normative standards. Source: personal collaboration

33.9 IT infrastructure Adopted for the Specific Intervention.

Within this contract, a data sharing environment is provided by the client. The infrastructure will be accessible from the web by both the client and all parties involved in the process of design and construction. In the sharing platform will be uploaded all files in native extension of the various disciplines (*.rvt *.nwd) and files exported in open format (*.ifc). The portal will be structured according to the expected documentation and working groups. Through user profile accreditation section, one will have access to a digital environment organized according to the skills of the operator who will then have operational permissions differentiated. The ACDat (see previous chapter) will be flanked by a non-digital document sharing repository (ACDoc), at which will be stored hard copies of all the informational materials acquired/acquired/produced by the design, the archive will be made accessible to clients by appointment. In addition to using ACDat as a means of sharing project information, will use the internal network of the office in order to make the best use of the computing powers of the hardware and software equipment.

33.10 Data Exchange Formats

The following identifies the expected data exchange formats for the job order in relation to the software used and because of the uses of the models subsequently identified.

EXCHANGE FORMAT OF DATA			
OBJECTIVE	FORMAT		note
	OPEN	Owner	
BIM Modeling STR-ARC-MEP	.ifc	.rvt	IFC 2x3 and mapping
2D graphical representation for documents project	.pdf A	..dwg	
Model review and interference analysis	.ifc	.rvt/.nwd	IFC 2x3 and mapping
Maintenance and management attributes	.ifc	.rvt	IFC 2x3 and mapping
Relations	.txt/.odt	.docx	
Estimated computations	.ifc	.cdf/.xls	IFC 2x3 and mapping
Construction time management	.ifc	.mpp/.nwd	
Report	.txt/.odt	.docx	
Shared parameters	.txt		
Key Notes	.txt		

Figure 50a. Data Exchange. Personal collaboration

Additional specifications for ensuring interoperability and reducing/eliminating data loss in the transition between proprietary and open format: In order to establish interoperable transitions based on *.ifc 2x3 format, the models will be optimized according to UNI EN ISO 16739 in order to avoid the loss of key data. Data integrity will be ensured by the application of the following data passing dictionary (.ifc mapping - Extracted for purposes of OdGI)

Revit elements	IFC Type Product	Name Attribute of Type Product derived from
Column (IfcColumn)	IfcColumnType	Profile/Building Material name + profile size
Beam (IfcBeam)	IfcBeamType	Profile/Building Material name + profile size
Wall (IfcWall)	IfcWallType	Building Material/Composite name + thickness
Slab (IfcSlab)	IfcSlabType	Building Material/Composite name + thickness
Curtain Wall (IfcCurtainWall)	IfcCurtainWallType	"Curtain Wall Type" fix name
Curtain Wall Panel part (IfcPlate)	IfcPlateType	Panel type ("Main" or "Distinct") + panel size
Curtain Wall Frame part (IfcMember)	IfcMemberType	Frame type ("Boundary", "Mullion" or "Transom") + profile size
Door (IfcDoor)	IfcDoorStyle	Library Part name
Window (IfcWindow)	IfcWindowStyle	Library Part name
GDL-based Objects	e.g. IfcFurnitureType	Library Part name

Figure 50b. Data Exchange. Source: Prodim Document

The following is the expected interoperability matrix for the main software used and in relation to the data exchange formats provided for in the table above. Following a discussion with the client's BIM Manager, the management plan information will contain an adjustment of the table below.

Matrice interoperabilità								
Civil 3D	Tekla	Revit	Primus	Autocad	STR Vision CMP (opzionale)	Navisworks	Solibri Model Checker (opzionale)	Programmi principali
	.ifc	diretta/.ifc	.ifc/.txt/.csv	.dwg	.ifc	diretta/.ifc	.ifc	Civil 3D
		.ifc	.ifc/.txt/.csv	.dwg	.ifc	.ifc	.ifc	Tekla
			diretta/ifc	.dwg	.ifc	diretta/.ifc	.ifc	Revit
				.dwg	.ifc	.ifc	.ifc	Primus
					.dwg	.dwg	-	Autocad
						.ifc	.ifc	STR Vision CMP (opzionale)
							.ifc	Navisworks
								Solibri Model Checker (opzionale)

Figure 50c. Data Exchange. Source: Prodim Document

34 Modelling the Air Conditioning System in REVIT:

34.1 Modelling the Ductwork in REVIT

The Autodesk® Revit® MEP platform can calculate airflow rates and pressure drops on any properly defined system using the ductwork and pipework system families. ductwork as well enables the typical "drawn" documentation's graphics and the various ways this at various stages of a project can be depicted on a drawing sheet, regardless of whether the in-concept design, duct is shown as a single line, or in a construction issue, as a fully coordinated double line.

Rectangular, round, and oval ducts are the three primary duct types. They serve as the foundation for your documents and design. Ducts can be used in one of two ways: with the Placeholder Duct tool or the Duct tool. Layouts can be roughed in using placeholders in single-line mode.

The placeholders display only a single line regardless of the level of detail that is set, despite the fact that at first glance this appears to be identical to a view that is set to a coarse level of detail. Additionally, placeholders do not produce fittings when a duct run is designed, but they do indicate rises and declines symbolically. The duct can still be sized depending on airflow, elevation, and other factors because they still have access to all the design tools an engineer needs.

All of these duct types, whether they are temporary or regular, link to various mechanical devices and air terminals. Duct fittings and accessories are also displayed there. The user can easily establish supply, return, and exhaust systems by utilizing the fittings and accessories included with the standard installation.

However, as we implement, we should also take into account the advantages of developing more duct kinds that are appropriate for our company's standards and the way we work.

we will learn how to do the following things in this chapter:

Differentiate between level-hosted and hosted components

Put fittings on placeholder ducts to make ducts

Use the different duct routing choices and make duct fitting adjustments.

34.1.1 Modelling The First-Floor Ductwork as an Example of The Whole Project:

At the first glance, we will realize what is the difference between the AutoCAD file and the Revit file from the figure 51 and figure 52 which are showing the supply air and return air on the first floor of the project.

Figure 51: AutoCAD file of the project. Source: Prodim Document

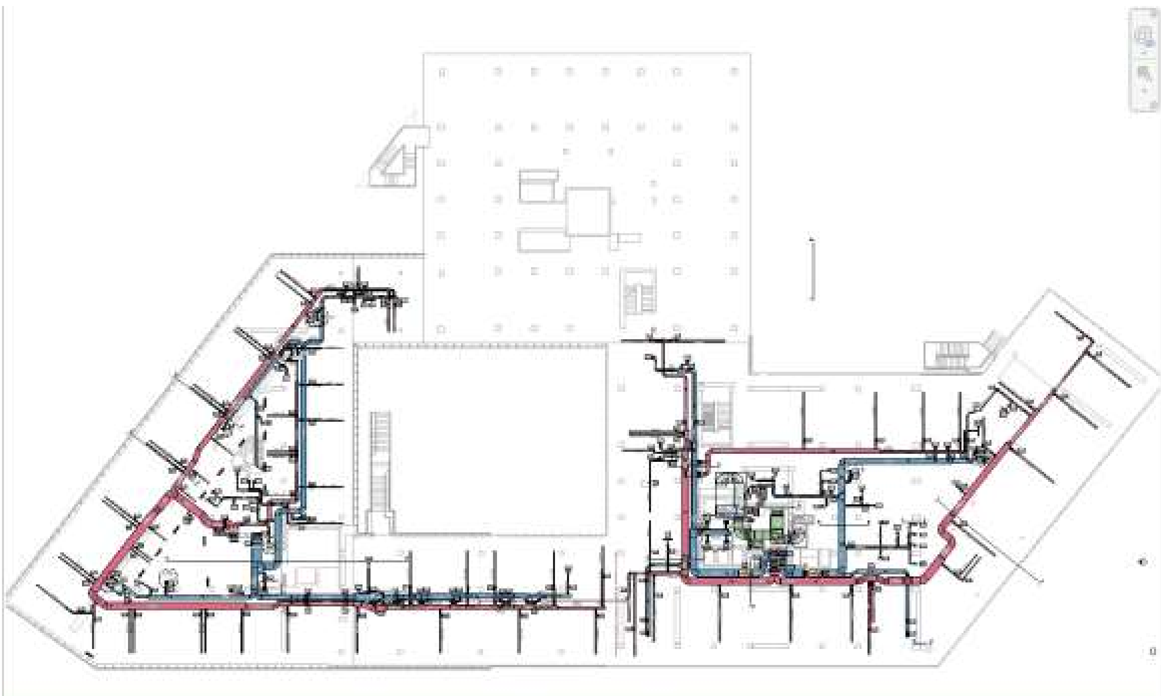


Figure 52: REVIT file of the project. Source: Prodim Document

34.2 Modelling the Air Handling Units in The REVIT

The air-conditioning or air-handling units, which are the mechanical air system's brains, can begin to function. as universal "boxes" with an exhaust and an intake. Despite their simple design and lack of manufacturer information, generic ACs and AHUs might have the same number of parameters as more intricate families. Comparable in size and functionality to standard ACs and AHUs, the idea at the phase of detail design, box can be replaced with a more detailed manufacturer or family with a construction-related problem, or even for several families if the AC/AHU unit has been built from the parts supplied by its maker (see Figure 53). However, it is very possible that when the more detailed manufacturer's family is loaded, the connectors in this generic unit won't be in the right place. This could indicate that additional effort is required to create a model that is more accurate.

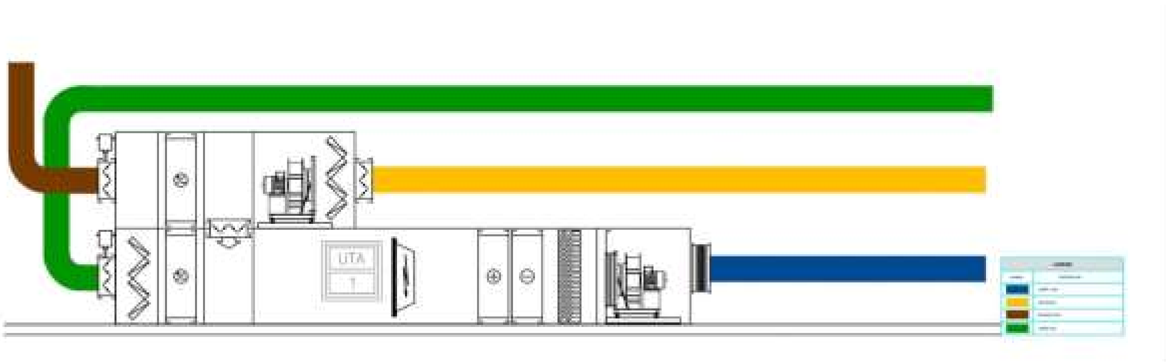


Figure 53. Air handling unit AutoCAD format. Source: Prodim Document

Figure 54. Air Handling Format of the Project REVIT format. Source: Prodim Document

34.3 Modelling the Fan Coil Piping System in the REVIT

The heart of a heating and cooling system is mechanical plumbing. The field may experience issues as a result of improper piping, and finding the pipes may take months. Both straightforward two-pipe systems and more intricate multi pipe systems exist. You can quickly view your routing possibilities and even compute the total volume of fluid in your system when utilizing the Autodesk Revit MEP 2015 program to lay out your systems. Apply the correct pipe material for routing the mechanical plumbing. By displaying the proper pipe sizes and fittings for that system, this arrangement is more accurate. To configure this effectively, a number of things need to be adjusted. The pipe kinds and settings are the most crucial factors. Additionally, we can change the pipe widths and segments as well as the fluids table as necessary. Here is a more in-depth explanation of each. Once these locations are established, you can focus on either automating or manually routing the pipes.

- Piping Systems
- Pipe Types
- Pipe Segments and Sizes
- Fluids Table

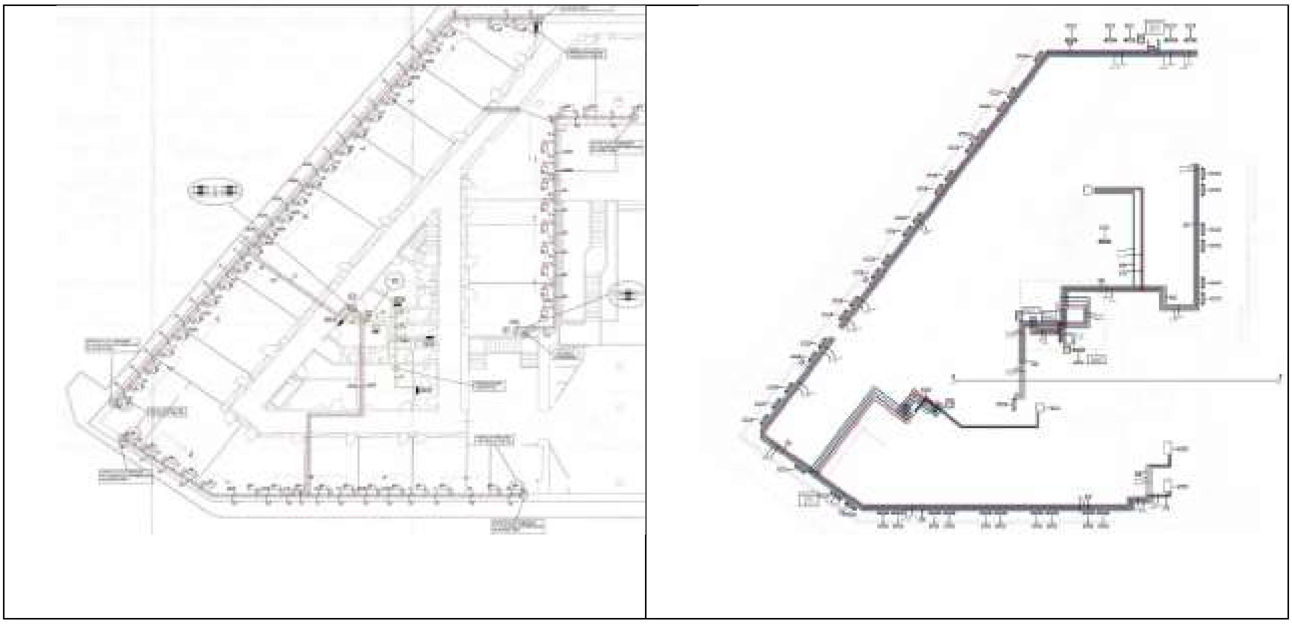


Figure 55. Modelling the Fan Coil Piping of the Project AutoCAD and REVIT format Source. Personal collaboration

35 Export Revit to Navisworks

we could anticipate that there will be some way for Revit and Navisworks to work together since they are both sold by the same firm. And there is a way to do it, or perhaps even two ways. When trying to export a file from one format to another, such as Revit to Navisworks, the actual conversion process is not too difficult. To ensure that there are as little to no issues during the conversion process as possible, we will need to do some preparations before attempting to convert Revit to Navisworks. Essentially, this means prepping your Revit model for conversion.

35.1 Preparation

The first area of preparation relates directly to models that are exported for use in 4D planning and other applications. In this scenario, it would be necessary to partition some of a model's larger or more intricate features in order to more easily fit them into a building planning timeline. Even the "Parts" feature in Revit can be very helpful with a work like this. A retaining wall is a great illustration of a model that requires subdivision. Even though you can model it in its whole in Revit, you'll need to divide it into many components that may be allocated to various building phases in order to fit it into the timetable. Verifying all of your Revit model's coordinates is another important subject here. All shared coordinates must be accurate because Navisworks combines multiple models into a single comprehensive model. Even while it is feasible to correct coordinate problems after exporting them to Navisworks, doing it beforehand is still much simpler. Additionally, since model export only converts what is visible from the designated view and excludes categories that are not directly related to the use of models, you will require a specialized view for the export process. It's a good idea to prepare a special name for an exported model; we can do this by appending the string "navisworks" to let the export tool recognize it as the model's default view. Last but not least, make sure that the appropriate detail level was selected in advance.

36 Exporting Revit files to Navisworks

When we wish to export Revit models to Navisworks files, there are actually two basic methods: either use Revit or open the model file in Navisworks. Although technically opening a Revit file in Navisworks is more of a conversion than an export procedure, we'll nevertheless include it because the setup and potential outcomes of both processes are similar.

1. Select the Revit menu.

2. Click the 'Export' tab.
3. Select the NWC format.

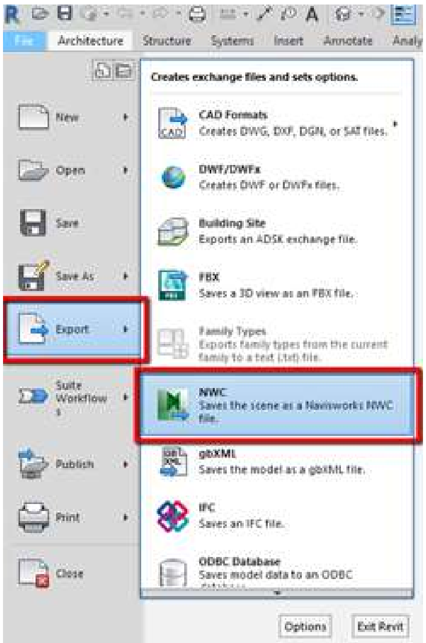


Figure 56. Select the NWC Format. Source: Personal collaboration

4. Click the 'Navisworks Settings' button at the bottom of the window.
5. Expand the 'File Reader' submenu.
6. Locate and set the Coordinates field to 'Shared'.

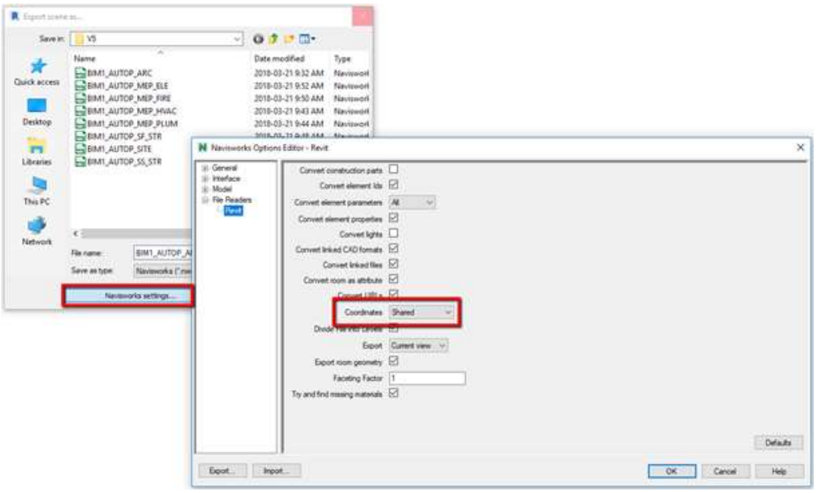


Figure 57. Navisworks Setting. Source: Personal collaboration

7. Import the NWC file into Navisworks and your model should now be properly positioned geographically.

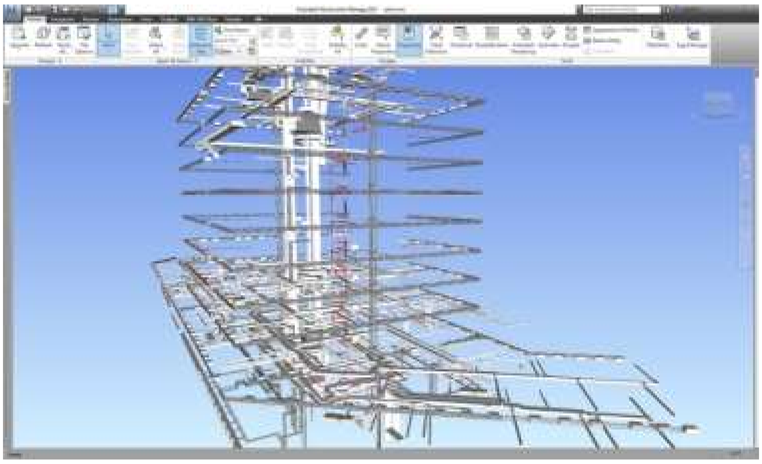


Figure 58. Navisworks of the Project. Source: personal collaboration

37 Overview of TimeLiner Tool in Navisworks

Autodesk Navisworks now includes schedule simulation thanks to the TimeLiner tool. Schedules are imported into TimeLiner from several sources. Then, we may link items in the model with tasks in the schedule to produce a simulation that enables us to compare scheduled dates to actual dates and understand how the schedule affects the model. The cost of a project can be tracked throughout its timeline by assigning costs to jobs. Depending on the outcomes of the simulation, TimeLiner also enables the export of images and animations. If either the model or the schedule is altered, TimeLiner will automatically update the simulation.

Figure 59. Navisworks Timeliner Source: Personal collaboration

In fact, it was the first and most important way to add tasks time to the Navisworks, there are other possibilities to add schedule time to the model by using tab data sources. By using that command, we are able to add tasks time from prepared resources such as CVS import, Microsoft Project MPE, Microsoft Project 2007-2013 (GANTT Chart) and so on.

Figure 60. Task in Navisworks Timeliner. Source: Personal collaboration

38 4D Simulation Project Using Navisworks Timeliner

After exporting the 3D REVIT model to Navisworks which have mentioned above, we open the file in Navisworks.

The first task we should do in Navisworks to simulate 4dimension modelling is finding the item according to the different possibilities which Navisworks gives us to use which are included Category, Property, Condition, and Value and according to our need and purpose, we are able to select any items with any levels as well as any materials and so on. And then we select the find all tab to find any items which are involved in that category. So, as it can be seen from the figure 61 firstly, finding the items, second, choosing the right category, third click on find all.

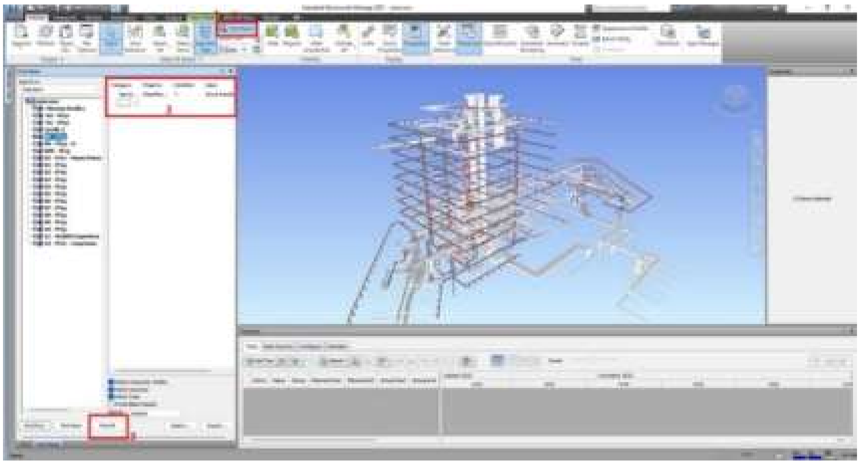


Figure 61. Select the element in Naviswork. Source: Personal collaborattion

The next task is setting the items we have already found from the tab sets to connect them to the scheduled time. Sometimes the item we chose may be hidden. There is a tab which helps us not only to unhide the selected item but also hide the whole of the items except selected items.

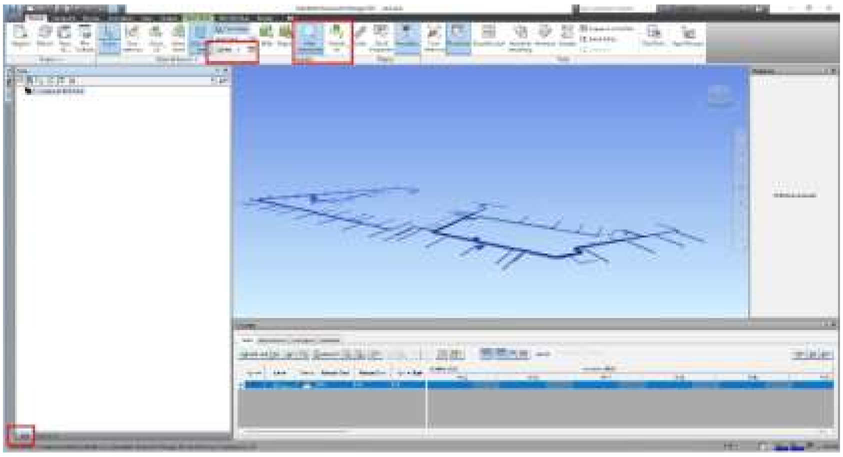


Figure 62: Setting the item in Nawisworks. Source: Personal collaboration

After that, we drag all the items we have already set to the attachment part of the timeLiner which is associate with the task. Also, we must choose the type of each task in the timeLiner tab.

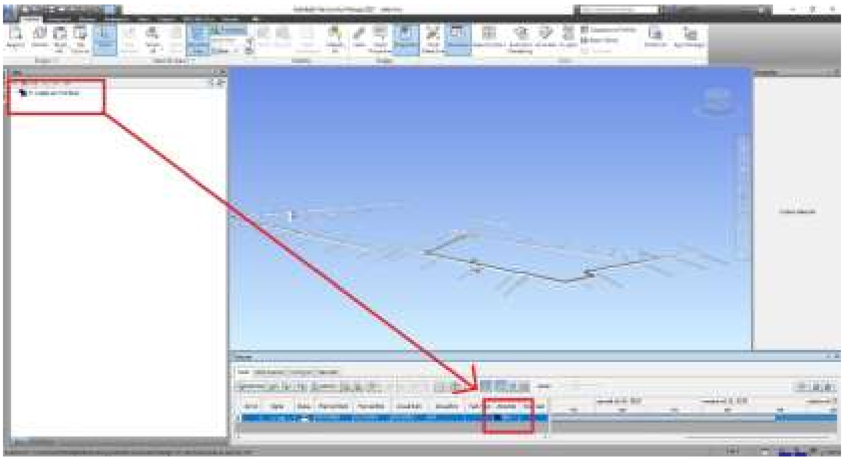


Figure 63. Drag item in naviswork to schedule section. Source: Personal collaboration

39 Simulation Settings and Running 4D Simulation

Now we are able to run the simulation after linking the model parts to particular timeLiner tasks. Start with the "setup tab," which is available for customizing the simulation, then set up the simulation by looking at the options accessible under the "simulate" tab. As shown in the figure.

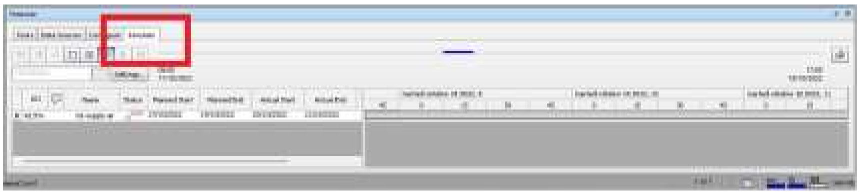


Figure 64. Simulation in Navisworks. Source: personal collaboration

40 Case Study Number Two

40.1 Introduction

In the contemporary digital era, process automation is happening more frequently. As a result, Building Information Modelling (BIM) is being used. Cost management is a crucial component of BIM technology. For cost analysis and budget monitoring, Building Information Modelling uses a 5D-cost model. Direct extraction of specific quantities and subsequent unit cost assignment are both possible with the 5D-cost model. The 5D-cost approach improves safety while lowering or using costs more effectively across the entire construction operation. The fifth dimension of BIM is a topic that is covered in the second part of the case study in this paper.

40.2 Different Methods to Calculate The 5 Dimension in the BIM System

The quantity takes-off is crucial to the cost-estimating process because a well-planned quantity take off can make cost-estimating less labour-intensive, quicker, and less likely to have human error-related omissions. For the cost estimate, a well-prepared quantity takes-off is essential since without a fully described the cost evaluation will be lacking without a record of the components that need to be valued. In the typical design process, precise cost estimation is only attainable once the documentation is finished, and the precise quantities of materials and labour are accessible. Prior to that point, at the idea stage and throughout the designing process, the cost is predicted using prior experience with similar buildings or established rates for a square meter of the same or similar construction type. Although it is possible to change the rates to suit a specific design, it is challenging to achieve accuracy levels that are appropriate. The rates are computed for conventional constructions. This is especially noticeable when unusual construction projects using new technologies are involved. Tools for basic cost estimation based on the automatic quantity take-off are available in design systems like Autodesk Revit and Tekla Structures, but the tools do not allow for any supplementary positions. In Italy, the most widely used BIM cost estimation software is PriMus-IFC which is used in our case study.

40.3 Explanation of The Complex Building of Second Case Study

The complex building which will be the second case study called Kuadra school which is located in Cuneo in Piedmonte region, Northern Italy, the capital of the province of Cuneo, the fourth largest of Italy's provinces by area.

Figure 65. Kuadra School 3D, Source: Kuadra company

The project is around 12050 square meters in three floors, one basement and consisting of sport hall which connected to the main building on the ground floor. Includes 40 classrooms, 4 of which are intended for outdoor education for about 1100 students. It has been made for 9 laboratories equipped with related service rooms as well as an audience with 256 seats. The sport hall with 256-seat audience, was designed in such a way as to have full independence operation regardless of the school plexus.

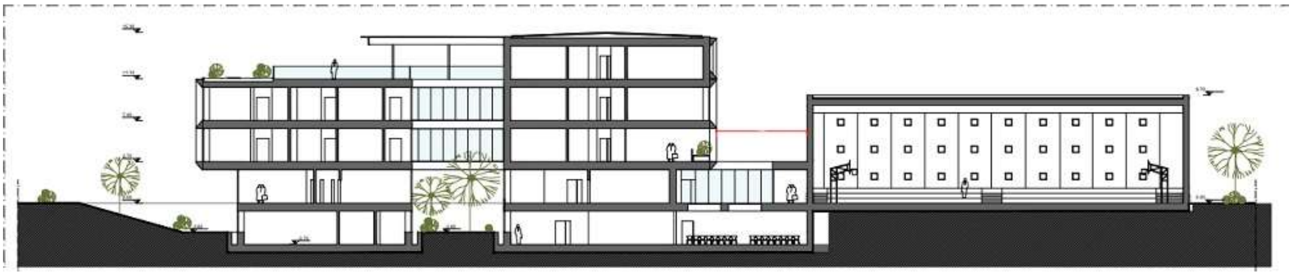


Figure 66. Kuadra school Section. Source: Prodim Document

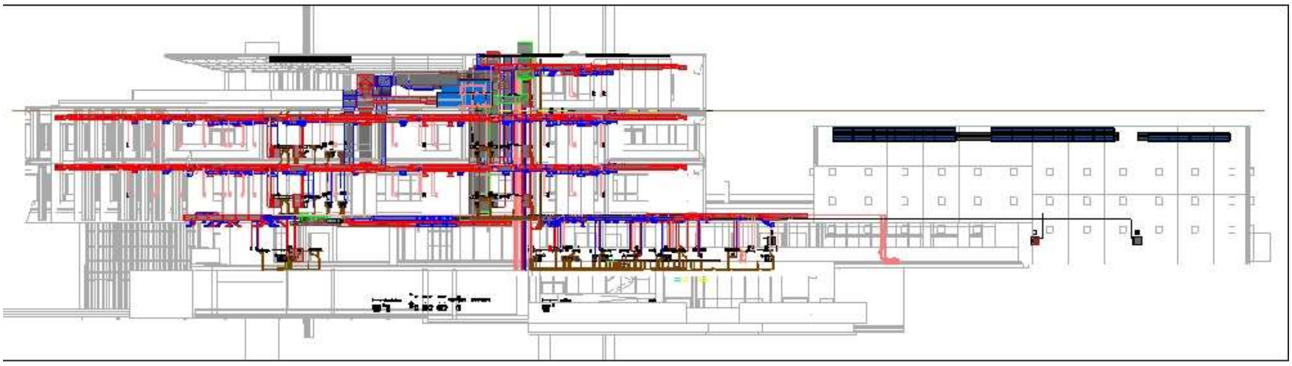


Figure 67. Kuadra School REVIT format. Source. Personal collaboration

Figure 68. Kuadra School. BIM Vision. Source. Personal Collaboration

As it is required to calculate the thermal load and coaling load which is essential to design and draw the air conditioning scheme systems for more forth use and as it has been done all calculations as well as all the 3D models of the air conditioning systems with REVIT software like the previous case study that it has been seen. Therefore, in order to avoid any resaid, we will go directly to the main purpose of the case study which is the 5dimension or estimating the cost of the air conditioning system by using the PriMus-IFC software as it was said that the 3D model has been done with the Revit software.

40.4 Creating The IFC File Format with BIM Software

The first step to use PriMus-IFC software is to change the Revit file format to IFC format as the PriMus-IFC software works with IFC file format. To achieve this purpose, we go first generate the 3D model with the BIM authoring software then choose the File option from the menu toolbar after that click on Export > IFC format. Define the relevant export settings and finally click OK to export the IFC file.

Figure 69. Creating IFC Format. Source: Personal Collaboration

41 Working with PriMus-IFC software

PriMus-IFC is the 5D BIM software for automatic and visual Quantity Take off tasks using BIM models saved in the IFC format that can automatically identify the entity types in your 3D BIM model and guide us in creating the necessary measurement rules, in order to:

- For each BIM object utilized in the project, get the automatic quantity take-off.
- Control the entities that are immediately accounted for on the 3D model visually.
- Even if the model needs to be modified to reflect changes, rely on a continually updated quantity take-off.
- Generate quantity take-off patterns and put on them to other BIM model projects.

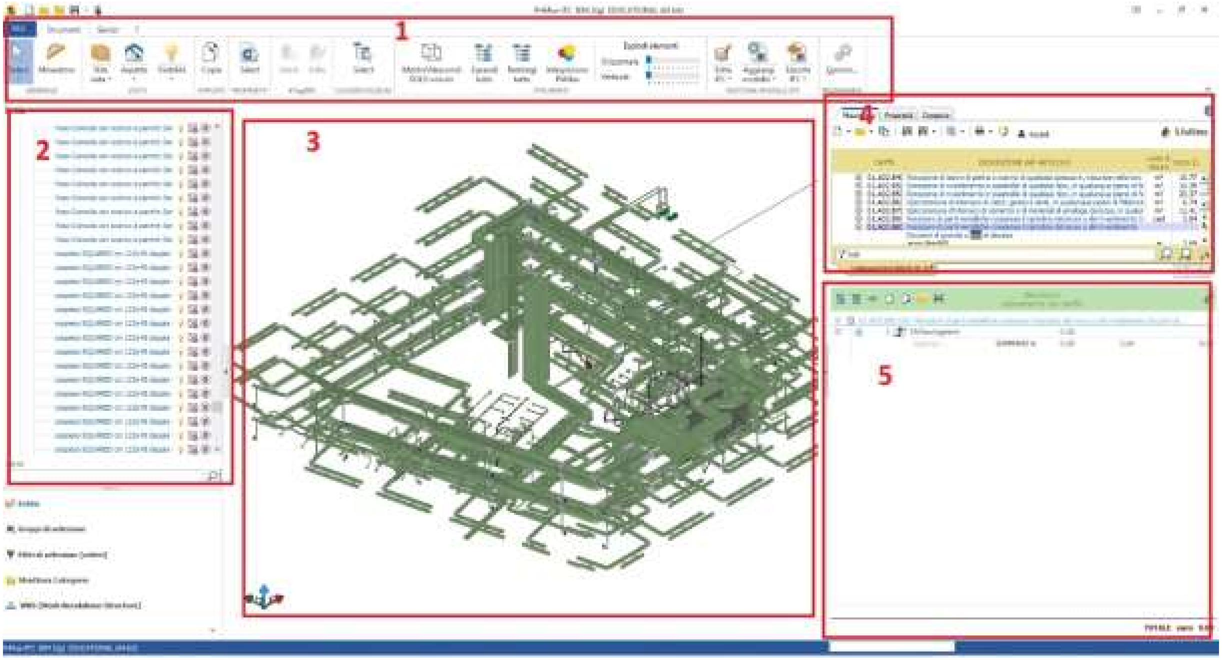


Figure 70. Primus-IFC Software. Source. Personal Collaboration

42 The Main Features of the Software

1. The main section is the toolbar on the top which consist of all the tools to create, modify, add or cut any models to the software.
2. When we add any IFC 3D model to the software we will be able to control all the elements by either selecting or unselecting all the elements to manage and control better the process.
3. This is the biggest part of the software which shows us the whole 3D model to see all the elements with high resolution.
4. As it can be seen from view number 4 is dedicated to showing the reference prices that we can add to the software by all the access tools which are on the top of this segment.
5. After selecting the right in for the selected item we can calculate the price for that element in that part of the software such as controlling the length, weight, and so on.

43 Pipeline Estimation Cost of the Project

The first step to estimate the cost of the pipeline of the project is to upload the IFC model to the software therefore, we open the software first and then create the IFC document file which is shown in the figure below.

Figure 71. Upload File In Primus-IFC Software. Source. Personal Collaboration

The second phase is to select the element or elements that we want to find the quantity take off which in our case is pipelines. After choosing the elements the colour of the selected element will change from green to red as can be seen in figure, 72.

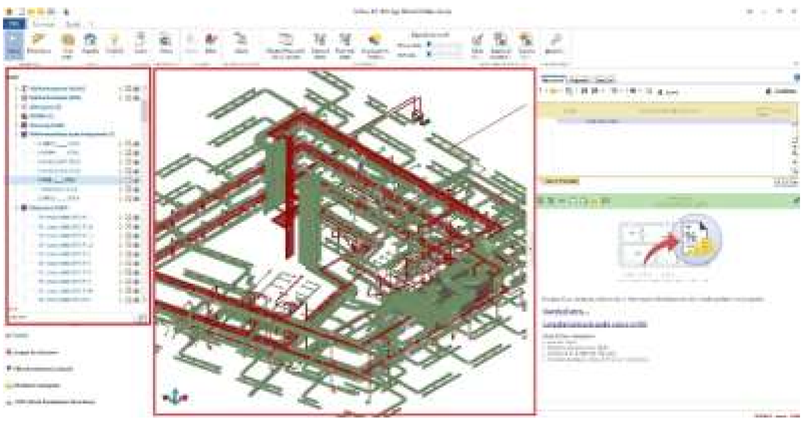


Figure 72. Select Item In Primus-IFC Software. Source: Personal Collaboration

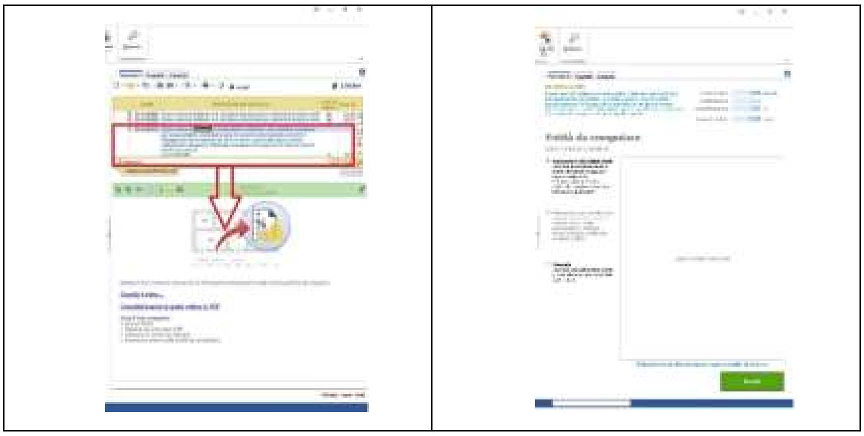
The next step which is one of the most important steps are selecting the right list of reference prices for the element which in our case is official Prezzario Regione Piemonte 2021/2022

Figure 73. Price list of Piemonte Region source: Piemonte Region

To achieve this is needed to select the right list of the reference from the measurements toolbar as it has shown in the figure 74.

Figure 74. List Price of Primus-IFC Software. Source: Personal Collaboration

By selecting the right reference and right category for our element which in our case is the piping line and more to the point distribution pipeline for the underfloor heating which is called AC (Aqua Calda 38) we need to drag the item of the price to the below category in order to be able to modify and read any specific detail of this element. After dragging the item to the below picture the windows from that will change and there is time to select the element to find out the length of that to be able to find the final price for that element.



Now it is time to select the item to be measured the length. In fact, there are three possibilities to select the right item from the 3D model in the software as it can be seen from the figure 75. First select automatically all the elements similar to our element that is not specific, secondly, automatically select all the elements with only that specific name that is the best choice for our purpose, and finally select the elements manually which is time-consuming.

Figure 75. Possibilities to Select Items in Primus-IFC Software. Source: Personal Collaboration

In figure 76 we can see all the technical details which we and to measure the price of the elements such as whole length, the name of the elements, and so on. After checking all the details with on click we move forward to the next level which will be the final step to measure the quantity take off the element.

Figure 76. Technical Details of the Element In PriMus-IFC Software Source. Personal Collaboration

In this section, we can create the measurements to be applied. Such as the title of the rules, modifying the length, height, or even the height of the measurement we desire to be applied to calculate the quantity take off even by creating the new formula for each of them.

Figure 77. Create The Rules for Measurement of the Element. Source: Personal Collaboration

The final step of quantity takes off is to see the computation and save the result. In PriMus_IFC there is a possibility to see the result directly in the software as it can be seen in figure 78 number one or save the file with different format like DCF, XLSX, DOCX number 2. Also, it is possible to print the result with all the details from the software number 2

Figure 78. Result in PriMus-IFC Software. Source. Personal collaboration

45 Conclusion

Building Information Modelling (BIM) method particularly in Heating, Ventilation and Air Conditioning (HVAC) systems allows engineers not only increased control all the elements of the project but also improved the effectiveness of the experts' teamwork.

In this thesis examined and reported the effects of Building Information Modelling (BIM) procedures on the construction projects. In particular, the fourth (4D) and fifth (5D) dimensions are used to investigate new possibilities for better project control.

By creating the project's overall work breakdown structure HVAC systems through the BIM system, which is an instrument for making the job more manageable and approachable. I have divided the entire project into digestible bits of work that are quickly monitored and estimated schedule, and cost, on their own. Using TimeLiner directly from Navisworks software, the 4D process included time scheduling for the entire project. It included estimated start and finish times as well as codes to specifically identify each family or element used in the model which allow us to manage and absorb the whole project from the start up to the end and monitor the whole project in 3D view. The final section of the thesis uses a 5D BIM quantity take-off to estimate the project's HVAC overall cost. The quantities take-off has been calculated using PriMus-IFC software, which all the REVIT models exported to by IFC format comparing to the usual method which is tiring and time consuming task for the engineers.

Overall, many beneficial results have been achieved during carrying out this thesis regardless of the difficulties.

In fact, 4D allows us to connect and balance project plan tasks with 3D model elements. By visualizing the workflow and the duration of each task, we can set different request schedules. Also we were able to: 1) Identify issues that are not visible on traditional timelines. 2) better and faster construction process 3) Analyse what the construct process will appear Various project phases. 4) identify and resolve potential dynamic interference between Various teams on site. 5) project runs more effectively and with shorter life cycle.

Moreover,5D simulation allows us to create models that recognize how changes are made Materials, layout, construction methods, and other design factors can effect this Infrastructure layout and associated costs. This helps identify the resource used over time and reducing the number of wasted materials.

In conclusion, applying Building Information Modelling (BIM) system is open to everyone from architects to HVAC engineers to manufacturers can benefits not only in the wide-range of communication and collaboration but also to construct the infrastructure and processes required either of existing advantages today or greater benefits to be carried within BIM in the future.

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