Comparative Perspectives: Exploring Workflow Efficiencies of BIM and CAD in 3D Modelling

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ABSTRACT

Building Information Modelling (BIM) is a new technology to make genuine project contributions, especially in the industry, architecture, and construction sectors. However, in practice, many professional workforces choose *computer-aided design* (CAD) as the primary technology*, which* has formerly appeared and is further comprehensible. *Building Information Modelling* offered different perspectives on purpose to facilitate designers or architects to expertise in various fields*. Building Information Modelling* (BIM) contains informative data that can use some expertise as a solution to make the occupation more coherent. This research aims to comprehend the workflow differences between *Computer Aided Design* (CAD) and *Building Information Modelling* (BIM) system technology. We collated methods by reviewing some literature and reviewing case studies. Then, we compare the workflow and conclude which is more effective for architectural design. In this research, we explore the difference between BIM's workflow and Cad's workflow to know which is more effective. So, we conclude and can apply the technology appropriately in the workflow needed so that it can simplify the workflow.

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1. INTRODUCTION

Software is one of the design processes architects need to do. In the past, CAD was the most popular software for architects to advocate for the design process. Computer-aided design or CAD is software for sketch modeling for developing conceptual projects. With the development of the times, science, and technology, BIM-based software began to be developed. The BIM concept was developed around the 1970s. BIM terms appeared first in G. A. van Nderveen and F. P. Toiman's paper in 1920. Still, unfortunately, BIM did not experience a growth in popularity for the next ten years [1]. The comparison between BIM and CAD has become a topic often debated about which is more effective and efficient. BIM is one of the ideal software that can accommodate all physical and intrinsic information about building models of related objects [2]. BIM can provide several benefits in the architectural design process, increase production efficiency, and bring new design innovations. CAD was only used for 2D sketch modeling [3]. Afterward, 3D modeling began to evolve. The 3D modeling process in BIM started with building modeling that was accompanied by various pieces of

information [4]. BIM is a new approach in the construction world that improves workflows and expands work systems that can coherently accommodate various work fields. The architecture world, which gives the actual form of development, is constantly required to adapt to the development of existing technology. To do that, the government mandates rules for adjusting the usage of BIM.

The inclusion of the concept of BIM as a new workflow still needs to be received by all actors in the construction world. It was the same as the beginning of the introduction of the CAD system, which had several obstacles. There is plenty of doubt about the capabilities of BIM workflows, considering whether they are compatible with project requirements and the hardware specifications used or not [5]. Workflow in an architectural bureau is the process of unifying all expertise in one organization that is applied coherently. It was quite a challenging stage of work. The limitations of software and hardware in accommodating data, which needs to be documented and stored in several fields, are quite numerous. BIM can anticipate this phenomenon so all related projects' data can be stored in digital form simultaneously. Based on the explanation above, the purpose of the research about "Differences in Workflow Identification Between BIM and CAD in Architectural Design" is to compare BIM workflow with conventional CAD at an architect's firm.

2. RESEARCH METHOD

This research is based on a research method that involves comprehensive academic observation of literature studies and related research papers, which aims to gain a basic understanding and a deeper reference regarding workflow and design process strategies through BIM and CAD. We took some CAD and BIM-related papers as our references in this study and used 15 of them in our research as the base theory. In this research, a case study comparison between two buildings (one building using CAD and another using BIM) was also carried out between two design processes to identify the workflow of each BIM and CAD design process. We also did a case study on a personal project that used BIM and CAD to locate and compare the workflow. The focus of the identification was to cover the advantages and disadvantages of comparing the two workflows. Based on the study results and identification, a conclusion will be drawn regarding considering the most effective workflow in the design process. Recommendations will also be provided based on research findings, which can be used as reference material for future research.

3. RESULTS AND DISCUSSION

3.1. Literature Review

3.1.1 CAD and BIM Concept Overview

CAD (Computer-Aided Drawing) is when we use a computer to create technical drawings. Technical drawing is like making drawings by hand; only we use a computer as a tool. However, it is different because computer-aided design involves collaboration between the computer and the designer. When discussing CAD (Computer-Aided Design), it usually refers to using graphic software to create three-dimensional models of components and assemblies. However, "design" here also includes all kinds of functions related to modeling and analysis [6].

Building Information Modeling is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting Building Information Model is a data-rich, object-oriented, intelligent, and parametric digital representation of the facility [7]. The main difference between BIM and conventional 3D CAD is how they describe and manage building information. Traditional 3D CAD describes buildings through independent 3D views, such as plans, sections, and elevations. Editing one of these views requires changes to all other views, which can introduce errors and cause inaccurate documentation. Additionally, data in conventional 3D images is limited to graphic elements such as lines, arcs, and circles [8].

3.1.2 Comparison of Workflow Using CAD and BIM in The Design Process

The project work cycle can be shortened using the proper methods and tools. A delicate modeling process can be continued to the next construction stage. A process that can be carried out on an ongoing basis will create a more effective and efficient process atmosphere [9].

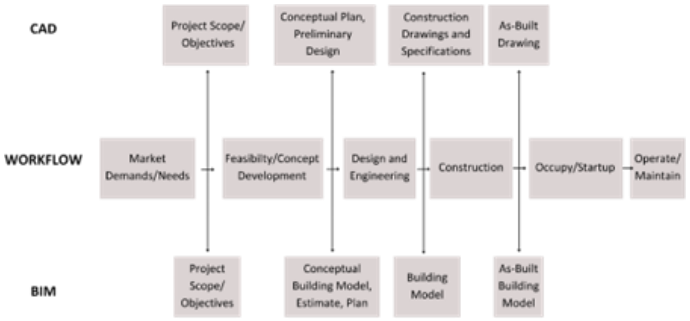

Figure 1. Workflow Comparison Scheme between BIM and CAD
Source: Sacks Eastman, Charles M., Lee, Ghang, Teicholz, Paul M., 2018

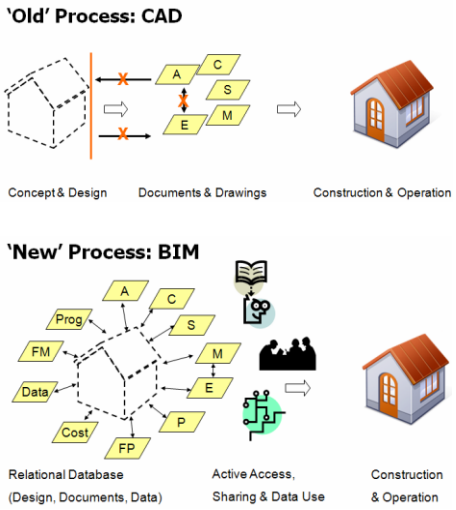

Figure 2. A Comparison between Conventional CAD and the new BIM Approach
Source: Azhar S., Nadeem A., Mok J., Leung B., 2008

3.1.3 CAD Workflow Impact and Advantages

Based on the book François Lévy, Jeffrey W. Ouellette - BIM for Design Firms_ Data Rich Architecture at Small and Medium Scales-Wiley (2019) Design process workflow using CAD parts into several parts, first starting from a sketch as a tool to create an initial concept of design, architects use CAD software to draw first-hand sketches of their design ideas. This sketch step is a medium for expressing architectural ideas and the general layout of the building. Then, proceed with the rendering or modeling process via CAD to create a digital building model that is more detailed than the design, as a step for visualizing and presenting the building model to clients.

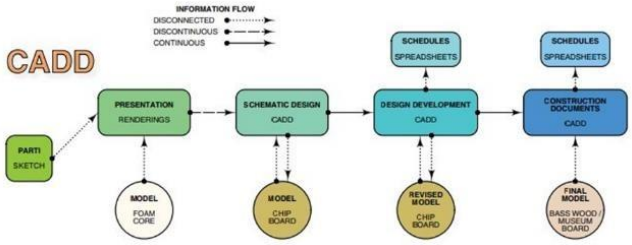

Figure 3. CAD Workflow.
Source: Lévy F, Ouellette J, 2019

This 3D modeling also allows architects and clients to see the design from various points of view. After modeling as an initial form of visualization, a schematic design is developed, including steps related to material selection, interior layout, and main design elements. CAD tools are used to arrange these elements in the 3D model. At the architectural stage, one will add details such as walls, doors, windows, roofs, and other supporting components. During this process, there may also be various revisions and improvements in response to client feedback. In the end, Architectural Building construction documents will be created. These documents include technical drawings, structural plans, mechanical layout, electricity, and other construction details as support and reference for contractors and construction teams during the construction process so that the building conforms to the approved architectural design.

CAD uses computers and special software to create drawings and computer models of products or designs. It helps people in various fields, including architecture, to produce highly detailed three-dimensional drawings and accurate two-dimensional drawings. CAD allows architects to create detailed designs and facilitates the design process, especially for complex projects [7]. However, to maximize its benefits, architects may need to understand more about CAD software because CAD software is not integrated between one function and another. So, using a lot of software to work on a large project is necessary. However, for simpler projects, using CAD is very effective because it is simpler and can reduce costs for the design process.

3.1.4 BIM Workflow Impact and Advantages

The Bureau of Architecture has several stages in processing the design. At the stage of creating design concepts that require critical thinking to develop creative solutions and interactive 3D modeling, the sketch is needed to express the main idea. The architecture bureau often criticizes design concepts such as reviewing aesthetic aspects, cost, time, and labor. In BIM, several generative approaches through digital technology can help provide ideas / extended brains for an architect in making concepts. When the concept is completed, the architect bureau analyses it for construction purposes so that the design process can run optimally and efficiently. In conventional CAD technology, this analysis process is quite time-consuming because it is not integrated between design and analysis. In BIM, the automated analysis process is incorporated into one BIM ecosystem.

There are several advantages to the BIM system: The modeling process is integrated with the analysis process, construction documents can provide attractive visualizations and more accurate calculations, Changes are interrelated, can estimate the costs needed for construction, and can improve collaboration between related fields. In detail, it can be categorized as follows:

1. BIM combines all data related to building objects created to provide complex and interrelated results and create simulations of existing buildings to analyze them.
2. It can analyze useful design experiments to produce innovative designs to create sustainable energy efficiency.
3. The combination of design and construction processes helps the architectural firm to determine the right design.
4. It is more accurate because changes are integrated, and data visualization is complex.
5. Interdisciplinary collaboration [12].

3.2. Case Study

3.2.1 Case Study of Using CAD in the Design Process: Guggenheim Museum Bilbao

Guggenheim Museum Bilbao is a modern and contemporary art museum in Bilbao, Spain. The museum was designed by Canadian American architect Frank Gehry and was inaugurated in 1997. The abstract shape of the building, which looks like it is twisted and moving, makes the museum unique. Apart from that, the appearance of the building façade also looks textured like fish scales and reflects a silvery color because it uses a steel frame construction coated with titanium [13].

In the design process, Gehry still uses sketches and handcrafted models to create initial concepts as the first step, a non-digital design process. Then, he used digital methods for the following steps: the design development step, detailed design, and digital fabrication. In the digital process, Gehry began the design process by examining virtual models created with CATIA software and mockups produced with Computer-Aided Manufacturing (CAM). After going through the design development process by examining the models, the CATIA master model will be sent to the contractor, who will review and develop the

detailed design and shop drawings.

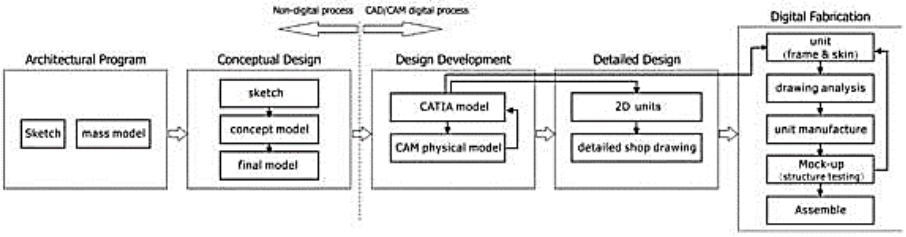

Figure 4. Design Workflow of Guggenheim Museum Bilbao
Source: (Lim, 2010)

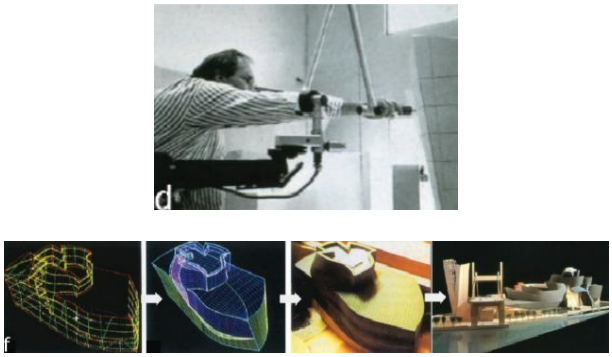

Figure 5. Gehry Examined the Virtual Model and The Physical Model
Source: Lim, 2010

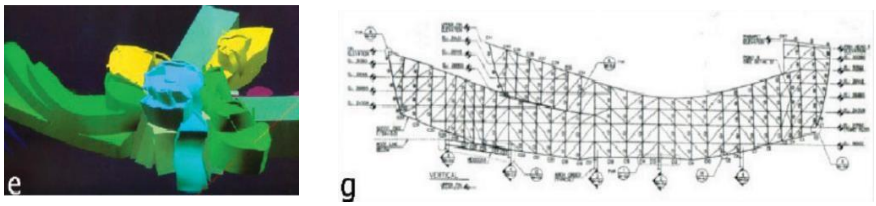

Figure 6. Detailed Design Process
Source: Lim, 2010

The final process of the Guggenheim Museum Bilbao's design is digital fabrication. At this stage, the 3D model is divided into frames and skin. Structural and curve curves were also analyzed to rationalize the design into a standard unit process. At this stage, a 1:1 mockup was created to test the structure and others, such as wind tests. After the analysis and tests were completed, mass production of 1:1 mockup began, and they were assembled on-site to test the structure and wind effects. During the whole process, the data of the CATIA model are exclusively utilized to maintain communication between architects and contractors. Also, the entire digital construction process is made as precise as possible so that time and budget during construction can also be well-controlled.

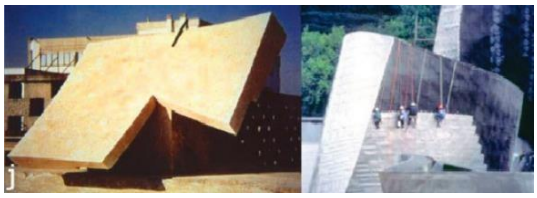

Figure 7. 1:1 Mockup That Assembled on The Site
Source: Lim, 2010

3.2.2 Case Study of Using BIM In the Design Process: Optimizing H-BIM Workflow for Interventions on Historical Building Elements

Historical building intervention initiatives depend on the quality of interdisciplinary data sets, including their collection, organization, and semantics. In this case study, the object used is a building facade element in the form of an entrance. The modeling object is created parametrically by collecting data from laser scanning, photogrammetry, 3D scanning, manual measurement, and documentation of historical research [15]. This data collection will make it possible to control the construction geometry of the door elements. It can be imported into the BIM system to create a more comprehensive, flexible, and information-rich modeling archive, which will help maintain, upkeep, research, and manage historic buildings. Semantic models in this workflow also use ontologies to provide an accurate knowledge of representation concepts, relationships, and rules like historical building.

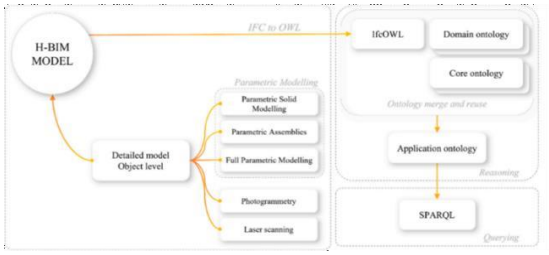

Figure 8. Design Workflow of HBIM Model
Source: Guerra et al., 2022

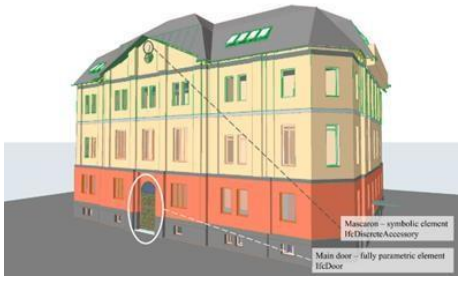

Figure 9. H-BIM Modelling
Source: Guerra et al, 2022

Modeling attention has been entirely given to the detail of the main door by using an IFC parametric element. By using these methods, the model can be connected to a BIM environment. The next step is related to semantic modeling. Semantic modeling is. The process of changing data that is initially relational, such as data in the Building Information Modeling (BIM) model, into data that is richer in meaning and has a more profound context will be explained in more detail as follows:

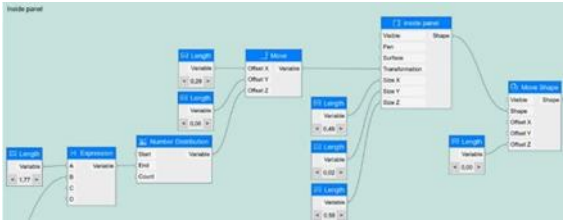

Figure 10. Algorithm of parameter design of the building's main door
Source: Guerra et al, 2022

The semantic Modeling section focuses on transforming BIM relational data structures into semantic data structures in an ontology. The proposed ontology is Erlangen CRM/OWL (ECRM), which is planned for historic buildings. This ontology includes classes, subclasses, and examples specific to the intervention stage of historical development. In addition, this ontology also integrates "Person Core Vocabulary" to identify who is involved in this project. After gathering all the information on geometric and semantics, the building model is now eligible to be exported as an IfcOWL model. The workflow process combines the IfcOWL format with domain and core ontologies aspects. BIM workflow integration allows designers to focus on digital modeling using one single system. Using semantic technology combined with BIM improves the management of specific information about the required data.

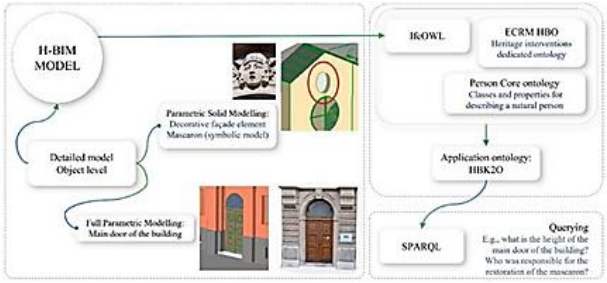

Figure 11. Workflow Summary
Source: Guerra et al., 2022

3.2.3 Case Study on Personal Project by Using Sketch Up: Gedung Kawung

Based on a personal case study, there are several stages or processes, and the first stage is a sketch. Sketches at this stage are used as the initial stage of the process of making design models in SketchUp; in these processes, the sketch can be done by using the default toolbar in SketchUp, which has basic commands such as creating lines, circles, polygons, text. After making a sketch, the next stage continues to create a design using 3D modeling using commands, push, pull, offset, and dimensions. This process requires manually grouping and layering of several lines, points, and areas. These layering commands also need to be edited manually for the material on each 3D plane, making it quite tiring for designers to edit each individually. After completing 3D modeling using Sketchup, creating 2D technical drawings is continued using other CAD applications, such as AutoCAD. 2D drawing starts from the beginning, and each image (elevation, section, and floorplan) is created one by one separately.

Figure 12. Sketch using Sketch Up

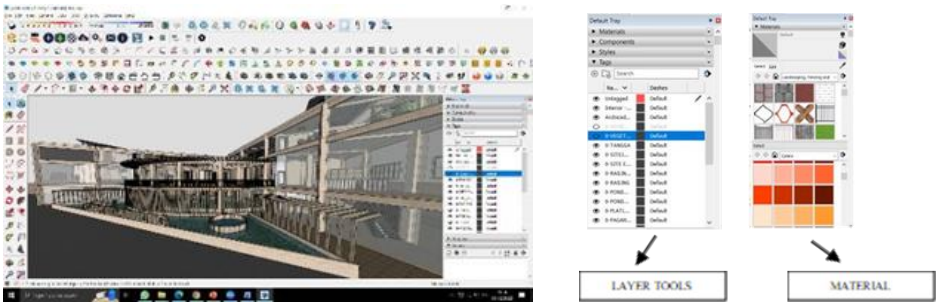

Figure 13. Setting Layers and Materials

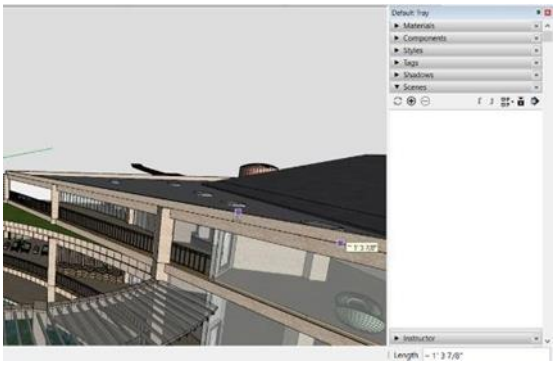

Figure 14. Measuring and Data Information

Figure 15. Sketchup as CAD Workflow

3.2.4 Case Study on Personal Project by Using BIM (ArchiCAD): Gedung Kawung

The design process in ArchiCad starts with creating grid lines as a guideline; Archicad, as BIM, is not integrated with lines or points as guides, so a line reference needs to be made to make design work more accessible. The default toolbar in ArchiCad has commands to create building elements or materials directly. This direct method is because Archicad requires a composite material base to integrate with volume calculations. The Archicad toolbar has commands that can create flexible or parametric shapes using the morph tool and the shell tool as a supporting tool in creating free/parametric shapes.

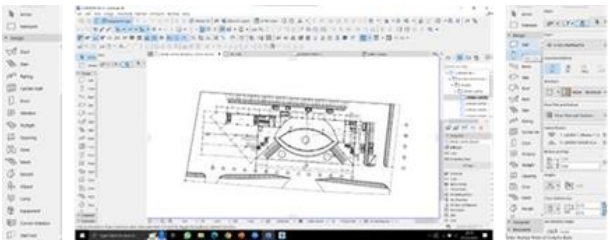

Figure 16. Sketching using BIM (ArchiCAD)

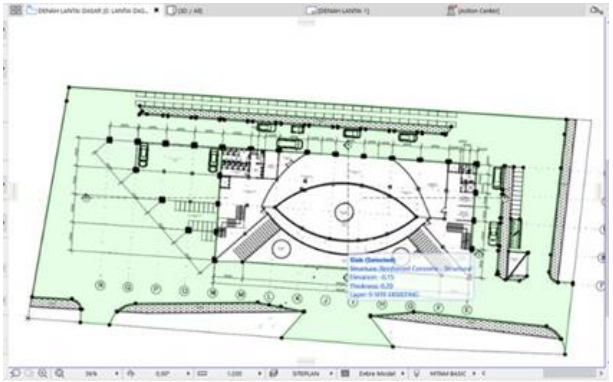

Figure 17. Sketching using BIM (ArchiCAD)

The data and information obtained when clicking on one of the elements or materials in the Archicad software is complete. The available data relates to information on design elements such as height, type of material composition, color, volume, area, and so forth.

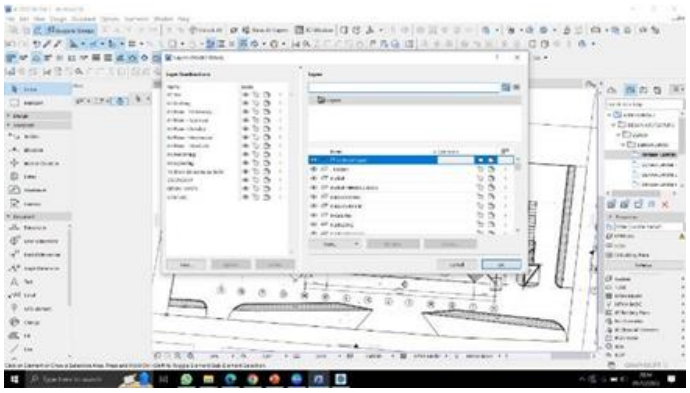

Figure 18. Sketching using BIM (ArchiCAD)

In Archicad, layers refer to the model view layers, and their use is segmented into two primary purposes: one for a layer of the drawing model and another for the materials layer. In the context of a BIM 3D model, when creating a 2D model accurately, considering the correct height and selected building materials or components directly influences the 3D model. In addition to 3D drawings, it is easier for us as designers to save time because detailed drawings or working drawings can be completed in one integrated 3D model.

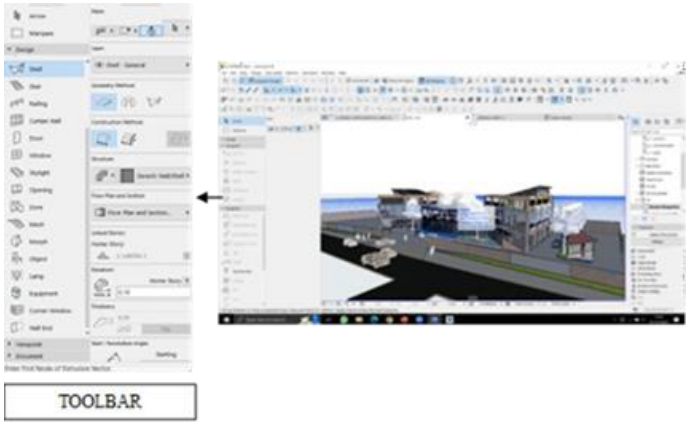

Figure 19. Sketching using BIM (ArchiCAD)

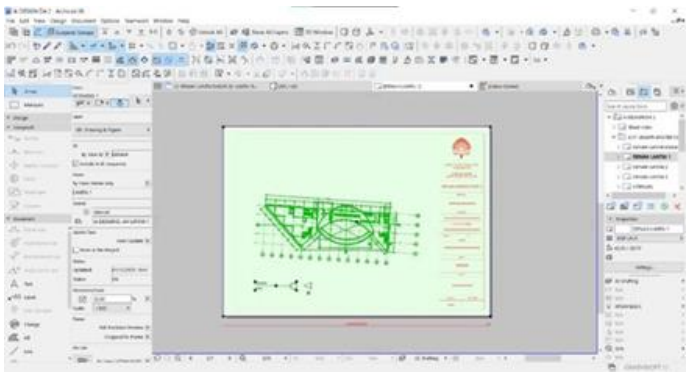

Figure 20. Sketching using BIM (ArchiCAD)

3.3. Comparison of CAD and BIM Efficiency in Case Studies

After reviewing some case studies by modeling with BIM and modeling with conventional CAD, here is the conclusion comparison we got:

Table 1. Comparison of CAD And BIM Efficiency in Case Studies

DESIGN MODELLING WITH BIM	CONVENTIONAL CAD WITHOUT BIM
Design modeling with BIM helps create efficient designs. The designer is provided with the ability to develop detailed data and model information using one single modeling system. Designers are also allowed to create optional designs and simplify the revision process. Works like this also indirectly increase the efficiency of the designer's working time.	The design process with CAD is more linear because it focuses more on 2D and 3D drawings. To produce various types of architectural drawings also requires different software because CAD software is not integrated. So, modifying the design is quite troublesome compared to using BIM, resulting in designers who could be more efficient in creating optional ideas.
A Designer often uses multiple design software, with data integration in BIM enabling synchronization between these various platforms. Synchronization between platforms makes data transfer between applications smoother, improving collaboration between team members using different design tools.	Modeling with CAD is also more flexible, where designers can prioritize creative ideas created by the designer's hands without parameters and mathematical calculations.
However, it is essential to remember that the BIM modeling system is related to parameters. Hence, designers certainly need more skills when they want to model a particular structure or shape that is more flexible.	Thus, CAD is highly recommended and more efficient on small-scale projects because drawing using CAD is more flexible than BIM. Architects can focus more on detailed drawings and modeling.

4. CONCLUSION

BIM (Building Information Modeling) and CAD (Computer-Aided Design) are two different methods of approaching the design and construction process, which cannot simply be compared to which is better or worse. We took a paper that focused on workflow. We also detail literature studies derived from documents by comparing them to case studies we conducted directly. The choice to use BIM or CAD should always be based on a deep understanding of the specific needs and goals of the project at hand. With its ability to cover 3D aspects of buildings integrated with related data, BIM is suitable for complex design processes, enabling efficient team collaboration, in-depth analysis, and integrated project management.

Meanwhile, on the other hand, CAD is also a reasonable and appropriate choice for working on projects that require a more straightforward design process, allowing for detailed technical design work and high-level planning. Therefore, deciding between BIM and CAD depends on understanding a project's specific needs and objectives and selecting the most appropriate approach to meet the project's demands. This alternative will be the most suitable if a design project can be completed through more straightforward and efficient stages.

However, it is necessary to underline the existing workflow in the CAD system. In CAD, there is no built-in integration with other aspects of the design process, such as time and cost management. Therefore, CAD is more linear and less comprehensive regarding data integration. For example, in the case study of Using CAD in the Design Process: Guggenheim Museum Bilbao, where that year, BIM was still a very optional system, Frank Gehry's design process used traditional methods in the form of manual sketches to create initial concepts as the first step, a non-digital design process. Then, for the next steps, the design development step, such as detailed design and digital fabrication, Frank Gehry integrated them into working drawings via CAD. Traditional work methods and CAD were the solutions that were considered to solve the problems at that time.

In BIM, the proposed workflow can improve knowledge-sharing and reuse among stakeholders involved in building projects by gathering all the information and data into one system. The workflow in BIM can facilitate conservation, rehabilitation, refurbishment, and retrofitting. For example, the author discusses the relevance of parametric modeling and the benefits of ontology reuse, reasoning, and querying mechanisms in the workflow. Also, the author suggests further research about connecting semantics technologies for optimal performance.

This case study emphasizes the value of BIM when implemented adequately on some projects; with BIM, we can optimize the integrated design process across all aspects of building planning and even provide an efficient system that can be replicated for future projects.

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