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COMPARISON STUDY OF CONVENTIONAL AND BIM-BASED APPROACH IN ESTIMATING THE CONSTRUCTION COST OF SUBSIDIZED HOUSING

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ABSTRACT

One of the most advanced systems and technologies in the field of architecture, engineering, and construction is Building Information Modeling (BIM). BIM enables the simulation of project information within a 3D model with an adjustable Level of Detail (LOD). Beyond 3D modeling, BIM has evolved to include up to 7D processes, making it a powerful tool for achieving effective and productive construction practices. Construction technology, including BIM, is crucial in enhancing productivity by addressing the growing demands placed on stakeholders to deliver projects efficiently, within shorter timelines, and with optimal results. Implementing BIM in quantity estimation workflows is one such method to improve operational effectiveness. This study aims to compare conventional methods and BIM by employing a comparative study approach, which focuses on identifying similarities and differences. The research object is a subsidized housing project in Central Java. During the project, volume calculations for roofs, walls, and floors were performed using conventional methods, followed by evaluations conducted with BIM. A comparison between the two methods reveals that BIM demonstrates superior average accuracy compared to manual methods. The findings indicate a significant cost difference between subsidized housing budgets calculated using BIM versus conventional methods. Specifically, the estimated BIM cost was over IDR 1 billion lower than that calculated using traditional techniques. This research concludes that integrating BIM in projects is essential for ensuring greater precision at every stage, thereby supporting higher design quality, informed decision-making, and overall project efficiency.

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1. Introduction

One of the most advanced systems and technologies in the field of architecture, engineering, and construction is Building Information Modeling (BIM). BIM enables the simulation of project information within a 3D model with an adjustable Level of Detail (LOD). Beyond 3D modeling, BIM has evolved to include up to the 7D model, making it a powerful tool for achieving effective and productive construction practices.

In Indonesia, a developing country, the number of construction projects continues to rise. Managing resources, such as materials, labor, and equipment, significantly impacts the overall performance of a project. The efficiency of construction projects can be assessed through four key aspects: time, cost, quality, and health and safety. Construction service providers are expected to complete projects more effectively and efficiently (Masdiana et al., 2024). In the current state of competition in construction practices, the stakeholders are required to complete construction projects quickly, with good quality, and at a minimum cost (Fauzi, 2021). A good concept is needed to cover all construction parts, starting from planning, design, procurement, and implementation in the field. BIM is a method that can increase the effectiveness and efficiency of carrying out construction work (Hatmoko, 2020).

In projects, problems often occur, be it design changes or changes to logistics planning. Construction project problems can increase costs and require quite a long time. The resources used are inefficient, so that they can disrupt further construction process activities (Huqban, 2020). Problems in construction projects can be minimized with information technology, especially the design at the beginning of the construction concept. Human resources are the most crucial aspect in the success of a project because achieving the triple constraint (cost, quality, and time) is related to productivity, quantity, and quality of workforce and material availability before the project is implemented (Nugroho, 2020). The rapid development of Indonesia has made way for many entrepreneurs to get involved in the construction sector. Still, in reality, in carrying out construction projects, many obstacles must be faced, including delays in work, which cause the duration of the work to be delayed, resulting in increased production costs and moral losses. As with other materials, many methods and concepts have been developed to minimize delays in completing work and avoid losses that will be incurred (Paikun, 2019). Many contractors experience delays in completing work that they did not previously predict where the delay can come from the owner or contractor, and if the owner causes the delay in completing work, the owner bears the loss, and vice versa. Furthermore, to minimize this, a concept is needed to avoid these losses (Aprilia, 2019).

The various benefits and advantages derived from the use of Building Information Modeling (BIM) include, among others, the seamless integration between design and construction. In Indonesia, the implementation of BIM has been incorporated into government regulations, leading to its increasingly widespread adoption (Nugrahini, 2020). One company currently using the Building Information Modeling (BIM) concept is a subsidized house in Central Java.

In the execution of construction projects, issues frequently arise due to the application of conventional or simplistic methods. Design changes, often adjusted to field conditions, can lead to increased construction costs, extended timelines, and inefficient use of resources (Artanti et al., 2022).

Construction projects that rely on conventional methods exhibit drawbacks, such as extended completion times and less precise outcomes, mainly when applied to large and complex projects. These challenges have driven the development of innovations aimed at addressing these issues. One such innovation currently being advanced is Building Information Modeling (BIM) (Alimin, M. et al., 2023). This study aims to evaluate the effectiveness of BIM implementation in construction projects compared to conventional methods.

BIM is a system, management approach, methodology, or workflow within a project that is implemented based on information related to all aspects of the building, which is then processed and projected into a 3D model (Sulistianto, 2022).

Building information modeling can be translated as a virtual process that covers all aspects, disciplines, and systems, allowing each team member (owner, architect, engineer, contractor, and provider) to collaborate more accurately and efficiently than conventional methods. There are several views in industry and academia on what is meant by BIM (Wibowo, 2020)

BIM is the process of generating and managing the building's data throughout its life cycle (Yudi, 2020). while Building information modeling represents the creation of digital models used during a facility's planning, design, construction, and operation stages. In addition, many definitions related to BIM have emerged with terms including object-oriented modeling, project modeling, virtual design and construction, virtual prototyping, integrated project database, and other newer terms of BIM (Enegbuma, 2014).

Previous research by Farras (2019) revealed that cost estimation using Revit Architecture was 1.47% higher than conventional methods. Another study on a similar topic, comparing BIM and conventional methods by Akhmad A. K. et al. (2019), presented contrasting findings: the use of BIM resulted in a 40.35% cost reduction, improved quality control with greater effectiveness and efficiency, and a time-saving advantage of 46.15% compared to conventional methods. Meanwhile, Zahro et al. (2021) found that costs derived from modeling with Autodesk Revit (BIM) were 5.33% higher than those using conventional methods. Additionally, the project schedule with Autodesk Revit was recorded as being 15 days longer than with conventional methods.

ArchiCAD allows the creation of a highly constructible 3D structural design or model regardless of material or structural complexity. Based on the advantages of Building Information Modeling (BIM), the author wants to apply it to the Subsidized House project in Central Java.

This paper aims to evaluate the application of BIM in terms of volume and cost estimation, comparing it to the conventional methods previously planned by the project team.

2. Literature Review

2.1. BIM In Construction

Discussing the Building Information Modeling (BIM) method inevitably involves examining its benefits to various stakeholders across different phases of its lifecycle. These benefits support and represent each stakeholder's roles and responsibilities (Mieslenna, 2019).

BIM is a methodology in which all information (specifications, quantities, prices, stages, work, etc.) is integrated with 3D building models that offer benefits, including cost and time control, coordination during efficient implementation, and optimizing infrastructure asset management (Krisbandono et al., 2019). Building Information Modeling (BIM) is most often defined as the process of creating a digital representation of the physical and functional characteristics of a building. These digital representations usually consist of a three-dimensional model that aids in the efficiency of the design and construction process.

BIM includes the information needed to see a project through the different phases. With the development of building projects, BIM can assist planners in creating architectural, structural, mechanical, electrical, and pipe building components (Hergunsel 2011). Another opinion is that BIM is an integrative tool for the built environment's design, representation, production, and long-term management. BIM software combines multi-dimensional visualization with a comprehensive, parametric database to facilitate collaborative design and facility management among project partners (Russell and Elger 2008).

According to Eastman et al. (2014), Building Information Modeling (BIM) is one of the most promising developments in the architectural, engineering, and construction (AEC) industry. One or more accurate virtual building models can be constructed digitally with BIM technology. They support design through its phases, enabling better analysis and control than manual processes. Upon completion, the resulting model contains the proper geometry and data required to support construction, fabrication, and procurement activities through the realized building. BIM also accommodates many functions needed to model the building life cycle, providing the basis for new design and construction capabilities, changing roles, and changing relationships among project teams. When appropriately used, BIM will facilitate a more integrated design and construction process that supports the realization of higher quality buildings at lower costs and faster project duration.

From the contractor side, BIM can help the estimator get more accurate estimated values of materials and costs (Olsen, 2017). Furthermore, BIM makes planning and design processes increasingly more precise and efficient (Khamil, 2019). The accuracy obtained at the design and estimation stages is obtained through collaboration, which allows the parties involved in construction activities to occur (Darko, 2020). Furthermore, BIM can be used for 3D visual communication, which with BIM makes the model more friendly to other users (Moreno, 2019)

In addition to the advantages that may occur due to the BIM concept, there are disadvantages to the BIM concept, such as human resource and financial problems related to implementing BIM. BIM-skilled human resources are still tricky to find due to the complexity of the BIM method (Olsen, 2017). Meanwhile, financial problems are related to procuring software and hardware supporting the BIM concept (Soekiman, 2021). This is because a large enough fund is needed to present the BIM concept in a construction project. Increased cost requirements will also occur along with the maintenance and supervision of hardware supporting the implementation of the BIM concept (Della, 2020).

People can define BIM differently due to perception, background, and experience. Some consider BIM an object-oriented modeling technology, while others claim that IFC is an intermediate data model for BIM (Khosrowshahi, 2012). Therefore, we need a definition that forms the basis of the BIM categorization. One of them is based on the level of implementation or what is referred to as the BIM maturity level (Jayasena, 2013). Bew-Richards defines the level of BIM implementation into 4 phases, which can be seen in the image below.

2.2. Construction Cost

Estimated construction cost, which in Indonesia also known as Rencana Anggaran Biaya (RAB), is a calculation of the costs required for materials, tools, and wages, as well as other expenses related to the implementation of the work or project. This RAB is also an essential reference for project implementation according to the design and initial agreement/contract. Without the RAB, there may be cost overruns due to the purchase of building materials that are not in accordance with the volume of work, uncontrolled wages for workers, inappropriate procurement of equipment, and various other negative impacts.

Preparing the Budget Plan (RAB) is based on the volume and unit prices calculated in advance. At the end of the amount, VAT (Value Added Tax) of 10% is usually added. When compiling a budget for a building, you first need to know what the budget is for. This will affect the method/system of preparation and the expected results. The time factor that the budget takes also determines how the budget is prepared. The stages of the RAB preparation process are as follows:

a. Cost analysis calculations are prepared considering work plans, technical planning requirements, and drawings.
b. The procurement of goods or equipment is calculated based on the location of the work.
c. Analyzing building costs involves analyzing SNI, wages, structure, and sequence. To make cost calculations easier, it is necessary to calculate the volume of work for each type of work in detail.

Detailed working drawings, commonly known as Detail Engineering Design (DED), are needed for several project requirements, including the preparation of the RAB. In addition, this DED can later be used to make a Building Permit (IMB) and a Work Contract Agreement (SPK). Using working drawings in the RAB for construction projects is necessary to determine the various types of work, specifications, and sizes of building materials. Preparing the DED for a construction project will make calculating the volume of work easier. This DED is the reference in determining the work items to be calculated in preparing the RAB.

The next step is to calculate the volume of work. This calculation is done by calculating the volume of work in one unit, for example, per m, m2, m3, or unit. The volume of work will be multiplied by the unit price so that the total cost of the work is obtained. The unit price of work can be separated into wages and material prices. We only need to enter prices based on market surveys that apply in the area. For example, according to PERMEN PUPERA No. 28 of 2016 Cipta Karya Sector, the unit price of work for measuring and installing Bouwplank is Rp. 81,732.- per m1, the usual excavation work for 1 m of land is Rp. 76,748,- per m^3. After the volume and unit price of work can be found, the next step is to transfer these figures so that the total cost of each work will be obtained (Job Volume x Unit Price).

The last step in preparing the RAB is to calculate the total amount of each sub-work, such as preparatory work, excavation work, foundation work, or superstructure work. These sub-jobs can be described in more detail. Each job is then totaled so that the total cost of the work is obtained, which is then reduced by the tax fee.

Preparing a Budget Plan, technically called Rencana Anggaran Biaya (RAB) in Indonesia, for a project is carried out before the construction process is started. The Cost Budget Plan (RAB) is the money required for wages and building materials in a construction job. This list contains the volume, unit price, and the total price of various materials and labor costs required to implement the project. The estimated cost is calculated based on the working drawings of the planning consultant and the specifications of the materials to be used. The essential data for calculating the RAB for the construction of Subsidized Housing is:

a. Working Drawings (Shop Drawing)
b. Technical specification / Requirement workplan (RKS)
c. Volumes, respectively, each work item in the picture
d. Bill Of Quantity (BQ)
e. List of prices for building materials and wages
f. Analysis of the unit price of work
g. Implementation work methods.

Figure 1 presents the research flow. After the owner has approved the shop drawings/work drawings, the next step is to calculate the volume of work. This volume calculation calculates the quantity of work items to be worked on so that the total cost of the work can be calculated later. Before calculating the RAB, the price of materials and wages must be determined and adjusted according to the applicable regulations on the site or location. The analysis of the unit price of work is a breakdown of the unit price. The unit price analysis of work describes what materials are used and what labor is needed for a work item. The unit price of work is the price used for a work item. The unit price is obtained from the analysis of the unit price of the work. The budget plan (RAB) calculates the volume of work multiplied by the unit price of work.

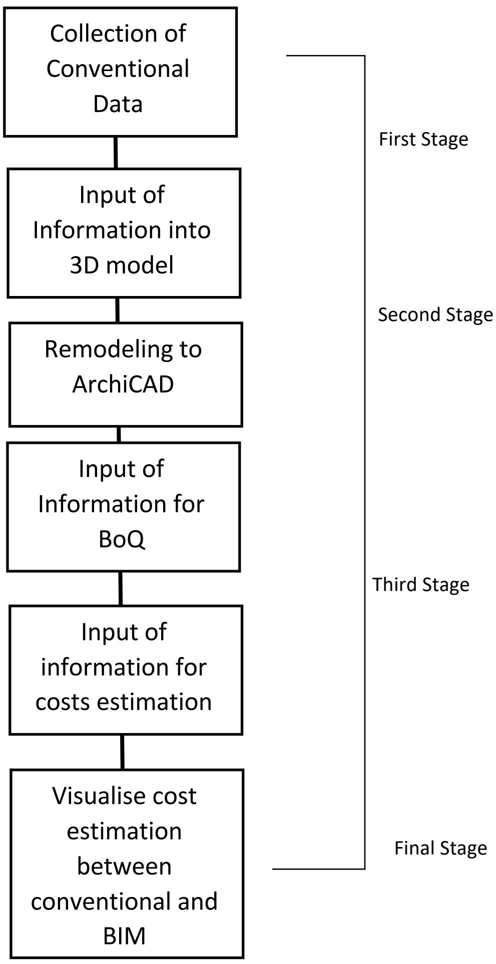

Figure 1. Research Flow

2.3. Software Support BIM

BIM software is needed as a supporting application medium, and its primary functions, which include MEP, structural, architectural, and 3D software (Reinhardt, 2009), are presented in Table 1.

Table 1. Software

Product Name	Manufacturer	Primary Function
AutoCAD Architecture	Autodesk	3D Architectural, Modeling, and Parametric Design
AutoCAD MEP	Autodesk	3D MEP Modeling
AutoCAD Civil 3D	AEC Design Group	Site Development
ArchiCAD	Graphisoft	3D Architectural Modeling

2.4. Archicad

ArchiCAD is a BIM CAD architecture software developed by Graphisoft of Hungary for Macintosh and Windows. Development of the original Apple Macintosh computer started in 1982. ArchiCAD was probably the first CAD product on a personal computer that could create both 2D and 3D drawings. In its first year, 1987, ArchiCAD became the first BIM implementation in the Graphisoft Virtual Building concept. It is currently used by more than 100,000 architects in the building design industry. ArchiCAD allows users to work with advanced data parametric objects, which users often call "smart objects." It differs from the working style of other CAD programs created in the 1980s. This product allows users to create "virtual" buildings using virtual structural elements such as walls, floors, roofs, doors, windows, and furniture. The program comes with a variety of customizable, ready-to-use objects.

ArchiCAD allows users to work with 2D or 3D representations on the screen. Two-dimensional images can be exported anytime, but the program's database models always store data in three dimensions. Plans, views, and sections are created from virtual three-dimensional building models and are constantly updated. Detailed drawings are based on enlarged model sections with additional 2D details. Third parties and several manufacturers of architectural products have developed libraries of architectural components for use in ArchiCAD.

The program includes the Geometric Description Language (GDL), used to create new components. ArchiCAD can import and export DWG, IFC DXF, and SketchUp files. Graphisoft is an active member of the International Alliance for Interoperability (IA), an industry organization that publishes standards for file architecture and data interoperability. CAD.

CAD software specializing in architecture. Because of the specialization of this field, ArchiCAD is software that is very easy to use in architectural design compared to general CAD software. Figure 2 presents an example of drawing results on ArchiCAD, which is a good idea for an architect to consider using ArchiCAD. Many conveniences can be obtained compared to using standard CAD software such as AutoCAD, SketchUp, Solidworks, and others because with standard CAD software, every object must be made from scratch, and even though we can use a library, we will still have problems if we want a customized object. That problem is answered in ArchiCAD, which has components and libraries based on parametric objects.

With object parameters, an architect can effortlessly change the size details according to needs. The concept of a parametric object is beneficial when an architect is modifying a design. For example, if you want to shift the position of a door or change the size of a window mounted on a wall, the hole in the wall will automatically shift and adjust size without any additional commands. Of course, this cannot be done with AutoCAD software or other software.

The advantages of ArchiCAD compared to other CAD software are the availability of communities and sources or references to support the learning process.

The resulting image is in the form of two outputs (windows), 2D (top view) and 3D (interactive), where the two outputs are active simultaneously and are connected, meaning that we can create images in any window and each other window will update each other automatically.

There is an excellent quality presentation rendering facility with an image or movie output. Graphicoft has released a special rendering software, Artlantis, which can render various image formats (not just ArchiCAD output) for better results. This software is also equipped with flythrough facilities, which are facilities for creating passive animations (the object is still, the camera is moving) from the images we have created.

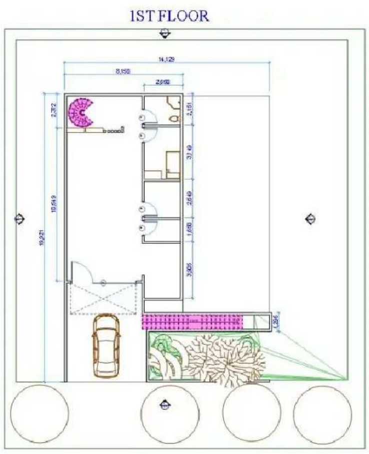

Figure 2. Drawing Example

Objects are equipped with very detailed size parameters, making it easier for us to get objects with sizes that are truly flexible. Fitted with the Bill of Materials or RAB calculation facilities, the format is quite good and acceptable to architects or contractors. The GDL facility, short for Geometric Description Language, is the creation of objects using a programming language script, similar to how we used to draw objects using Pascal or C languages. It is just that the GDL language is much simpler. Because with objects defined in the program language, the file size becomes very small because it only contains text. Therefore, it is very easy to disseminate.

It will be different if we want to share objects we draw using AutoCAD software. For example, if we're going to upload a car object with a complex shape in *.dwg/.dxh format because the file will be extensive. The concept is the same as depicting objects using PDMS software (special software for designing oil drilling refinery platforms), which outputs the images and text. With the file extension *.txt or *.mac.

2.5. BIM Dimension

BIM Dimensions are dimensions of using BIM as a process of digitally depicting a 3D form, which includes information that is grouped as follows, namely 3D (physical form: width, height, and depth), 4D (time), 5D (cost), 6D (sustainability), and 7D (facility management) (Thomas Goubau, 2016).

A 5D BIM encompasses the integration of assembly and objects within a BIM model, augmented with cost dimensions. This can be achieved by embedding cost data directly into the objects within the BIM model or by "directly linking" the model to cost estimation software, as implemented in New Zealand (Boon & Prigg, 2012). Furthermore, parametric modeling facilitates establishing relationships between elements, incorporating the specifications and characteristics of each element and object. Consequently, parametric modeling enables the extraction of comprehensive and accurate information from the model, which can be directly utilized for cost calculations (Eastman et al., 2011).

However, advancements in the implementation of 5D BIM continue to evolve. A recent survey of BIM users in the UK revealed that only 14% of respondents deemed traditional quantity takeoffs (schedules in New Zealand) irrelevant (National BIM Survey, 2013).

3. Research Method

This research was conducted using the comparative study method, which focuses on comparing two or more things that have similarities or differences owned by the research object.

This project was carried out in subsidized housing in Central Java. The house building consists of floors, walls, and roofs that will be assessed using BIM.

The quantity of work is analyzed based on the DED drawings from the planning consultant. Conventional methods are analyzed using Microsoft Excel to calculate the volume of existing work. Calculating the quantity of work based on BIM is done by modeling the structural elements as shown in the DED image. The structural elements modeled are the house's floors, walls, and roof.

You can use a simple comparison formula for the two methods to calculate the efficiency. To calculate efficiency, you can use equation (1)

$$\text{Efficiency} = \frac{(\text{Conventional Volume with BIM}) \text{X } 100\%}{\text{Conventional Volume}}$$

The material difference is obtained from the difference obtained by conventional methods and BIM with tools such as Archicad software.

4. Results and Discussions

Why should you use applications that carry the BIM concept in a project? Questions like these often arise regarding the benefits that can be generated from BIM applications. Below, the authors describe the benefits that can be generated by using BIM applications:

a. BIM applications have a 3D view that makes it easy to understand the drawing plans to be built (Soemardi, 2014).
b. Using BIM applications can make it easier to calculate the volume of work quickly and accurately (Baskoro, 2021).
c. BIM applications can provide information regarding costs or RAB for each work component, such as beams, columns, slabs, and so on, so we can predict and conclude estimated costs for each work component (Suwarni, 2021).
d. BIM applications can display 3D images on even complex jobs such as reinforcement in bridge structures (Raflis, 2018).
e. BIM applications are not just for displaying animated videos; the benefits are more for managing project information (Apria).
f. BIM applications in the early stages of work can be used as a reference for clash detection. When applied in the field, we can Determine whether the 2D plan drawings will result in collisions between components, especially between structural, architectural, and MEP drawings (Octavia, 2013).
g. Another benefit of BIM applications is that it facilitates coordination between stakeholders, contractors, and owners/consultants, who can coordinate anytime and anywhere. With the help of a computer network all work, all contractor work in the field can be accessed by the owner/consultant in real-time or can be responded to directly at that time.

Archicad software is a BIM application that creates 3D models that generate geometries with embedded information for the design and construction of infrastructure buildings. From this program, the heights, perspectives, details, and schedules of all the instruments needed to document building designs can be derived. An image created using Archicad is not a collection of 2D lines and shapes interpreted to represent a building but a live view taken from a virtual building model. These models are compilations of programs that contain geometric decisions at every stage of the process (Kirby et al., 2018).

BIM software helps architectural, engineering, and construction (AEC) teams create high-quality buildings and infrastructure. Archicad can be used for:

a. Build 3D models, structures, and systems with parametric, precision and ease.
b. Streamline documentation work with instant revisions to plans, elevations, schedules, and sections as projects change.
c. Empower multidisciplinary teams with specialized tools and a unified project environment.

The development of Archicad in Indonesia is relatively slow due to a lack of information and knowledge about this software. However, construction companies' interest in using this software is relatively high. Even though it is somewhat lagging, Archicad is now increasingly popular among construction workers.

The most significant drawback is the relatively high cost of software licenses and training. While most construction projects in Indonesia have successfully implemented BIM, several challenges remain to be addressed, such as the lack of synergy among project components due to limited understanding of BIM among most service users.

4.1 Comparison of Conventional and BIM Results

Table 1 compares the volume of roof work on roof structural components using the conventional and BIM methods. The differences in the obtained components occur due to the intersection between the beams of other structural elements. So that the BIM method for the roof will automatically be reduced. Based on the calculation of the volume of work, the volume obtained for the BIM truss roof method was 40.81 m2, while for the conventional roof truss method, the volume was received at 45.00 m2. So, the difference obtained from the two methods is 4.19 m2. Next, a table of analysis of the volume of roof truss work is presented. Then, using BIM is more efficient at 9.3%.

Table 3. Analysis of Roof Building Volume Results

Roof Work	Konvensional	BIM	Difference
Roof Trust	45.00 m^2	40.81 m^2	4,19 m^2
Roof Spandek	45.00 m^2	40.81 m^2	4,19 m^2

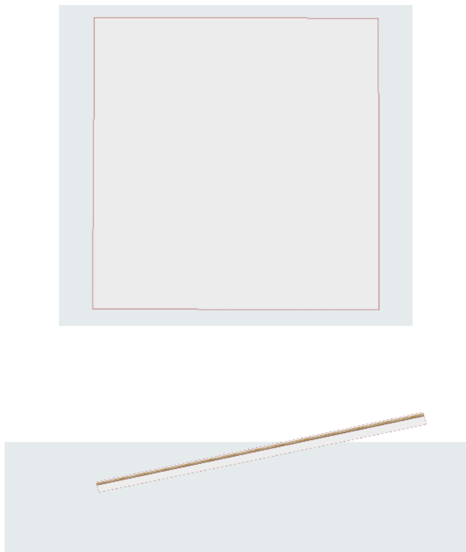

Figure 4. Roof Volume Results

Table 2. Analysis of Wall Building Volume Results

Wall work	Conventional	BIM	Difference
Light Brick Work	99.61 m^2	80.83 m^2	17.78 m^2

Based on data from Table 4 for calculating the volume of floor work, the results obtained for the volume of work for walls measuring 20x20 using the BIM method were 1.53 m2, and for floors measuring 40x40, it was 26.33 m2. Then, for the floor volume of the conventional method with a size of 20x20, a volume of 2.15 m2 is obtained, and for a tiled floor with a size of 40x40, a volume of 28.75 m2 is obtained. So, the difference obtained from the two methods is 3.04 m2 or 9.8%, and it is stated that BIM is more specific than conventional methods.

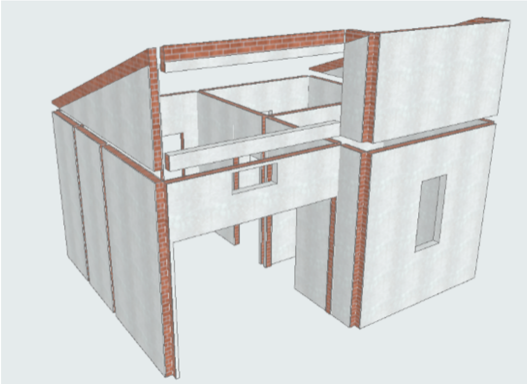

Figure 5. Surface Area Of The Wall Outside Face

Table 4. Surface Area Of The Wall Outside Face (Net)

80,83 m²

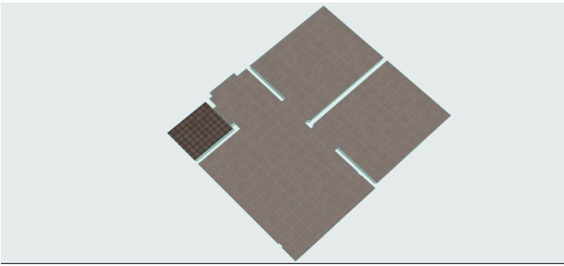

Figure 6. Floor Building Results

Table 5. Analysis of Floor Building Volume Results

Ceramic Work	Konvensional	BIM	Difference
40x40	28.75 m^2	26,33m^2	2,42 m^2
20x20	2.15m^2	1.53 m^2	0.62 m^2
20x20	**2.15m^2**	**1.53 m^2**	**0.62 m^2**

4.2. Comparison of costs

The next step is to analyze the RAB until it becomes RAB, where the author gets the company's Unit Price Analysis (AHS) in a Microsoft Excel file. The file is imported into the Archicad application for further analysis, and the volume is obtained from the previously imported model. To determine the volume in the framework of making a budget plan (RAB), the model is used as a reference so that errors can be minimized to as small as possible.

Calculating RAB (Budget Plan) with the conventional method requires quite a long time because it has to be calculated manually, namely mathematical geometry, to get the volume of work. Considering this for efficiency in planning and accuracy in estimating the budget plan for building construction, ArchiCAD software is used.

In research on planning, modeling, and analysis of subsidized housing structures in Central Java using the Building Information Modeling (BIM) method. Creating an initial structural model in the ArchiCAD application using the 3D concept is the first step for integration between the ArchiCAD application.

Table 6. Comparison of Development Costs

Work	Conventional	BIM
Frame Roof	Rp. 4.571.910	Rp.4.146.214
Covering Roof	Rp.4.346.730	Rp.3.942.001
Wall	Rp.7.831.803	Rp.6.419.680
Floor 40x40	Rp.4.007.875	Rp 3.670.517,3254
Floor 20x20	Rp 252.419	Rp 179.628

4.3. Quantity Material Take Off

Quantity material takeoff in construction refers to estimating materials, reviewing project plans, and gathering information about materials or materials used in a project. The quantity of material takeoff is one of the efforts to calculate the volume used as material for preparing BOQ for a project. The quantity of material takeoff does not consider the needs such as labor, insurance, equipment, or contingencies. Quantity material takeoff only focuses on volume and material requirements and then converts this information into a cost-based estimate. The method used in Quantity material takeoff is divided into two types, namely:

a. Quantity Material Takeoff Manual: This method is carried out by utilizing an estimator to manually detail and estimate the quantity of material determined from construction drawings without a computer's aid.
b. Quantity Material Takeoff materials are carried out with the help of computers and database applications, such as Microsoft Excel, CAD, and, most recently, BIM-based analysis.

4.4. Cost Construction

The volume of work is multiplied by the unit price. Tables 7-12 present the cost analysis and the calculation of RAB.

Table 7. Wall Cost Analysis (Conventional Method)

No.	Job Description	Units	Coefficient	Price/Units	Total Price (Rp)
A.	Labor				
1.	Worker	OH	0.15	120.000,00	18,000.00
2.	Bricklayer	OH	0.02	130.000,00	2,600.00
3.	Foreman	OH	0.013	150.000,00	1,950.00
4.	Foreman	OH	0.003	170.000,00	510.00
	Total Manpower Cost				23,060.00
B.	Material				
1.	Light Brick	Bh	8.33333	8.433.73	70,281.12
2.	Ready-to-Use Mortars	kg	0.473	1.500,00	709.50
	Total Price of Materials				70,990.62

No.	Job Description	Units	Coefficient	Price/Units	Total Price (Rp)
C.	Equipment				
D.	Total (A+B+C)				94,050.62
E.	Overheads and Profits		10% x D		9,450.06
F.	Labor Unit Price (D+E)				103,455.69

Table 8. Floor Cost Analysis (Conventional Method)

No.	Job Description	Units	Coefficient	Price/Units	Total Price (Rp)
A.	Labor				
1.	Worker	OH	0.2	120.000,00	24,000.00
2.	Bricklayer	OH	0.05	130.000,00	6,500.00
3.	Foreman	OH	0.035	150.000,00	5,250.00
4.	Foreman	OH	0.035	170.000,00	5,950.00
	Total Workforce Cost				41,700.00
B.	Material				
1.	Ceramic	Bh	25.0	3,000.00	75,00.00
2.	Portland cement	kg	10	1,500.000	15.000,00
3.	Color Cement	kg	1.5	1,625.00	2,437.50
4.	Muntilan sand	M3	0.045	212,500.00	9,562.50
	Total Price of Materials				102,000.00
C.	Equipment				
D.	Total (A+B+C)				143,700.00
E.	Overheads and Profits		10% x D		14,370.00
F.	Labor Unit Price (D+E)				158,070.00

Table 9. Roof Analysis (Conventional Method)

No.	Job Description	Units	Coefficient	Price/Units	Total Price (Rp)
A.	Labor				
1.	Worker	OH	0.1	120.000,00	12,000.00
2.	Bricklayer	OH	0.156	130.000,00	20,280.00
3.	Foreman	OH	0.117	150.000,00	17,550.00
4.	Foreman	OH	0.018	170.000,00	3.060.00
	Total workforce				**52,890.00**
B.	Material				
1.	C5-75.08	M'	1.20000	14,166.67	17,000.00
2.	Baut	Bh	1.6	210.00	336.00
3.	Reng	M’	1.3	6,166.67	22,200.00
	Total price of materials				39,536.00
C.	Equipment				
D.	Total (A+B+C)				92,426.00
E.	Overheads and Profits		10% x D		9,242.60
F.	Labor Unit Price (D+E)				101,668.60

Table 10. Wall Construction Cost (Conventional Method)

Work, light brick	98.61	M2	Rp. 79,422.13	Rp. 7,831,656.97
Plasterwork	149.22	M2	Rp. 27,214.00	Rp. 4,060.764.22
Ace's job	149.22	M2	Rp. 15, 174.50	Rp. 2,264,278.19

Table 11. Floor Construction Cost

Ceramic fitting work 40x40	28.75	M2	Rp. 139,404.38	Rp. 4,007,875.78
Ceramic fitting work 20x20	2.15	M2	Rp. 117,404.38	Rp. 252,419.41

Table 12. Roof Construction Cost

Roof truss work	45.00	M2	Rp. 101,598.20	Rp. 4,571,919.00
Spandex roof work	45.00	M2	Rp. 96,594.14	Rp. 4,346,736.43

Table 12. Comparison of BIM and Conventional

No.	Types of Jobs	BIM	Conventional
1.	Wall	Rp.6.419.680,00	Rp.7.831.803,00
2.	House floor	Rp.3.670.517,00	Rp.4.007.875,00
3.	Bathroom Floor	Rp. 179.628,00	Rp.252.419,00
4.	Roof truss	Rp.4.146.214,00	Rp.4.571.910,00
5.	Roof Cover	Rp.3.942.001,00	Rp.4.346.730,00

No.	Units	BIM	Conventional
1.	500	Rp.3.209.840.000,00	Rp.3.915.901.500,00
2.	500	Rp.1.835.258.500,00	Rp.2.003.937.500,00
3.	500	Rp.89.814.000,00	Rp.126.209.500,00
4.	500	Rp.2.073.107.000,00	Rp.2.285.955.000,00
5.	500	Rp.1.971.000.500,00	Rp.2.173.365.000,00

It can be derived from the table above that the difference between the BIM method and the conventional method amounts to IDR 1,326,348,500.00. The recapitulation of construction costs for the development of subsidized housing in Central Java is presented in Table 12. The table indicates that for the construction project of the first floor of subsidized housing in Central Java, there are three main work items: wall work, roof work, and floor work, where both contractor prices and SNI prices have been calculated based on the volume and unit of work. Overall, the BIM method demonstrates an economic difference of 12.63% compared to the conventional method.

This study aligns with Akhmad A. K. et al. (2019) findings, which concluded that cost estimation using the BIM method is 40.35% more economical than the conventional method. However, this study contrasts with the findings of Farras Faridah Putri (2019) and Zahro, P. K. et al. (2021), which stated that the BIM method is more expensive than the conventional method by 1.47% and 5.33%, respectively.

As outlined in Tables 7, 8, and 9, the economic value of a Bill of Quantities (BOQ) depends on the type of work items and sub-items. The tables also reveal that, overall, using the contractor or conventional method yields results with less precise accuracy. Based on the contractor or conventional method, there are several sub-items where the percentage difference between the conventional and BIM methods exceeds 10%. This is particularly evident in wall work, where volume calculation and window openings are performed without deducting the volume of these openings. Meanwhile, other work items fall within a percentage range of 3.79% to 9.09%. As shown in Table 12, large-scale projects exhibit significant price differences, with the BIM method proving to be more economical than the conventional method. From this data, it can be concluded that to maximize the economic efficiency of the BOQ for subsidized housing development in Central Java, it is recommended that all work items adopt the BIM method.

5. Conclusion

Based on this study, it can be concluded that significant differences in volume can be identified in unit price analysis when utilizing the BIM concept, ultimately contributing to project cost minimization. The Integrated Building Information Modeling (BIM) concept offers several advantages. First, integrating the Budget Plan (RAB) with the model expedites determining the volume of each work item, as quantities can be directly derived from the model. Second, integrating applications facilitates the selection of user-friendly modeling software and combines it within a single 4D and 5D analysis platform, namely Archicad. Third, integrating the RAB with the model simplifies explaining volume details to on-site contractors.

The use of BIM demonstrates a highly significant difference in the calculation of the Bill of Quantities (BOQ) between software-generated estimates and field measurements, as evidenced by the findings of this study.

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