Perception Comparison between the Physical Object and Virtual Model in Residential Project using BIM-based Virtual Reality

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Received June 24, 2024, Revised April 4, 2025, Accepted May 19, 2025, Published December 30, 2025

Abstract. *Traditional methods of presenting residential projects, such as show units and scale models, have undergone significant transformation. These methods typically required potential people to visit the site in person to fully understand the designs and visualize the proposed structures' spatial relationships and aesthetic impact. However, both of these traditional approaches can be time-consuming. This study aims to create a proposed system that integrates Building Information Modeling (BIM) and Virtual Reality (VR) to enhance the presentation process in the residential project and examine the difference between the perception of the virtual model and the physical object throughout the residential project. Thirty respondents participated in the experiment, which measured their perception scores regarding the dimensions of three types of bedrooms at the residential project named Icon Project 7 (I-Sport). The paired sample t-test was used to analyze the differences in perception scores between the virtual model and the physical object. The results indicated that perceptions of the virtual model were not significantly different from the physical object. In addition, the time required to implement the proposed system to create a virtual model of this case study is 4 hours, which is a significantly faster approach than the conventional method, reducing the lead time before the show unit can be showcased to prospective buyers. Additionally, implementing the proposed system involved an investment cost of 169,993.29 Baht and an operation cost of 20,000.00 Baht per month. The ability of these virtual models to effectively simulate physical objects enables residential projects to enhance presentations while reducing project time and expenses.*

Keywords: Building Information Modeling (BIM), Virtual Reality (VR), Perception, Virtual model, Physical object

1. Introduction

The construction sector is a significant contributor to Thailand's economy. However, recent data from the Office of the National Economic and Social Development Council (NESDC) indicates a declining trend in its contribution [1]. Within this sector, residential construction, encompassing single-family and multi-family housing, has experienced steadily increasing demand, particularly in urban areas. This growth is attributable to factors such as favorable interest rates, economic expansion, and heightened urbanization [2]. Consequently, private sector investment in residential projects has surged, leading to a proliferation of residential construction projects.

Traditionally, the presentation of residential projects has relied heavily on physical methods, such as show units and scale models. These approaches necessitate in-person visits by potential buyers to facilitate a comprehensive understanding of the design, spatial relationships, and aesthetic qualities of the proposed structures. However, these conventional methods present several limitations. Constructing show units and scale models is inherently time-consuming, requiring significant lead time before they can be showcased to prospective buyers. Furthermore, these physical representations may not fully capture the dynamic aspects of living space or allow for easy modification to reflect evolving design preferences. The inflexibility and time required for updates can pose challenges to developers seeking to adapt to market demands or incorporate buyer feedback efficiently. Because of these constraints, the need is apparent for more agile and adaptable methods of presentation.

In recent years, visualization technologies, specifically Building Information Modeling (BIM) and Virtual Reality (VR), have revolutionized the construction industry, offering capabilities that extend far beyond enhanced interaction and user interfaces compared to traditional methods. These immersive technologies provide a transformative experience that is reshaping the future of the field [3], improving project collaboration, communication, and management, as well as presenting and displaying complex data to stakeholders to facilitate problem-solving and informed decision-making.

A new approach, leveraging visualization technologies, has emerged for presenting residential projects through various virtual models that utilize advanced tools, such as Head-Mounted Displays (HMDs), as shown in Fig. 1. This innovative method not only reduces operating costs and time but also eliminates the need to construct physical show units and scale models for project presentations.

Figure 1. Head-Mounted Displays (HMDs).

The use of show units is inherently limited by the requirement for complete construction. Moreover, appearance and interior are key components of the significant factors related to buying decisions [4]. In contrast, the adoption of digital technologies offers superior flexibility, shorter lead times, lower costs, and unrestricted, convenient access. These advantages can significantly enhance the stimulation of purchasing decisions. Similar to Sookprasert and Parncharoen [5] indicated that Consumer acceptance of Virtual Reality (VR) technology exerts a significant influence on consumer purchase intention.

Despite significant advancements in Building Information Modeling (BIM) and Virtual Reality (VR) that aim to improve design collaboration and provide economic benefits for design professionals, there has been comparatively little focus on creating specialized BIM-based innovation systems designed specifically to enhance the presentation process for residential projects. Therefore, this study aims to develop a proposed system that integrates Building Information Modeling (BIM) and Virtual Reality (VR) to enhance the presentation process in the context of residential projects. Furthermore, the study investigates the perception between viewing a physical object such as show units and experiencing a Virtual Model in a residential project using BIM-based Virtual Reality.

2. Literature Review

2.1 Visualization technology in the residential construction project

Visualization technology is a powerful tool for enhancing communication [6] for the residential construction project. The advantages of visualization technology consist of displaying complex data that is easily understandable, enabling decision-making [7], and enabling interactions between owners and stakeholders to solve problems. Visualization technologies and tools such as Building Information Modeling (BIM) and Virtual Reality (VR) are available to enhance project communication and coordination in residential construction projects.

2.1.1 Building Information Modeling (BIM)

Building Information Modeling (BIM) was first conceptualized in the 1970s and is a digital representation of a building's physical and functional attributes. This comprehensive model incorporates diverse building data and information, serving as a valuable resource throughout the building's entire lifecycle, from conception to demolition. Meanwhile, Building Information Modeling (BIM) is a groundbreaking technology and process revolutionizing how buildings are envisioned, designed, constructed, and managed throughout their lifecycle [8]. In addition, this technology simulates, visualizes, and facilitates the virtual 3D coordination of project components, providing seamless access to all relevant information about project planning, design, construction, and operation processes [9].

2.1.2 Virtual Reality (VR)

Virtual Reality (VR) is a promising technology poised to enhance various aspects of construction projects, from design and construction to application and ongoing maintenance [10]. Meanwhile, Virtual Reality (VR) typically employs computer technology to enhance the user's imagination [10] and enable immersive interaction with a computer-generated 3D environment [11-12]. Additionally, common Virtual Reality (VR) systems include Head-Mounted Displays (HMDs), which provide visuals directly to the eyes and peripheral vision, and Cave Automatic Virtual Environments (CAVEs), which project visuals onto room walls. These systems stimulate various senses, such as sight, hearing, touch, and sometimes even smell, to create a convincing illusion of reality.

3. Research methodology

3.1 Project framework

The system architecture developed in this study comprises four key components consisting of 1) selecting the case study, 2) BIM authoring, 3) application authoring, and 4) the experiment of the proposed system. Overall, the study successfully demonstrated that integrating Building Information Modeling (BIM) and Virtual Reality (VR) can facilitate the automatic updating of digital models, ensure data storage in a standardized file format, and display a virtual model of the residential project in a virtual environment. Furthermore, this study posits that this approach can be an effective tool for homeowners, allowing them to quickly perceive and understand the information. Additionally, it can potentially advance the residential construction industry and be a beneficial application for site visits and communication among stakeholders involved in the project.

Fig. 2 presents the proposed system architecture, strongly emphasizing virtual information exchange. The Industry Foundation Classes (IFC) format was utilized for this study. Initially, a three-dimensional (3D) model of the case study was created using Autodesk Revit 2024, which was then integrated into the Enscape software to develop a virtual model within a virtual environment.

This study employed Head-Mounted Displays (HMDs) to provide respondents with a new experience via the walkthrough of the virtual model in the environment.

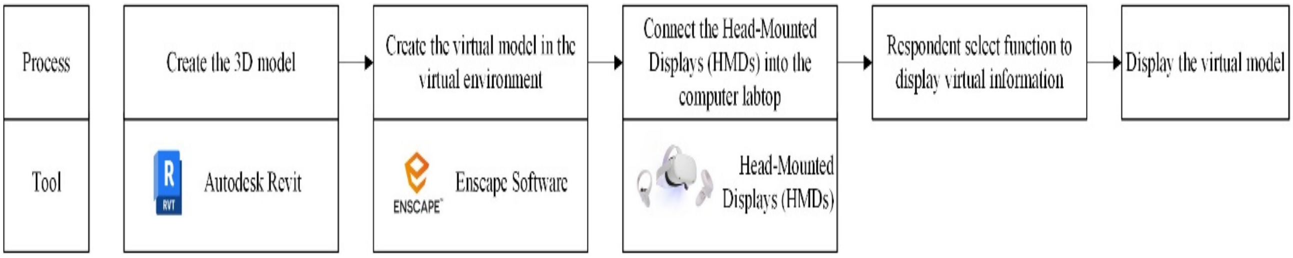

Figure 2. The framework of the proposed system.

3.2 Selecting the case study

This study focused on the As-built drawings of the residential project named Icon Project 7 (I-Sport) as a case study, which is a two-story building. The total area is 183.60 square meters, and the height of each floor is 3.50 meters, which raises concerns regarding the perception of improper dimensions. Therefore, to address these issues, a case study was conducted, and three types of bedrooms were selected for the experiment, consisting of the master bedroom, the second bedroom, and the sunny bedroom, respectively.

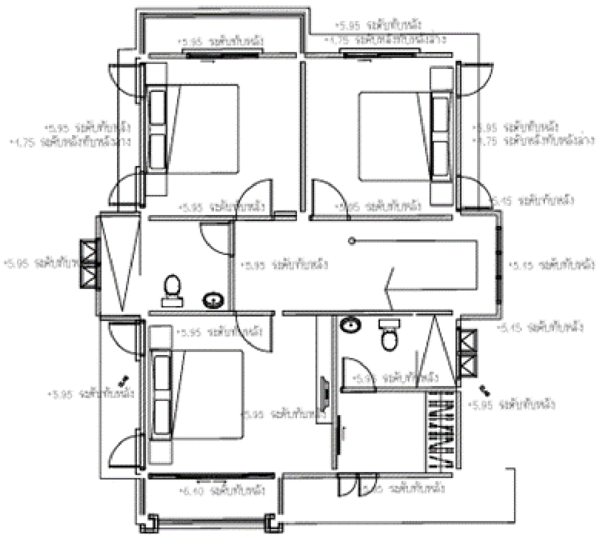

Figure 3. The As-Built drawing of the case study.

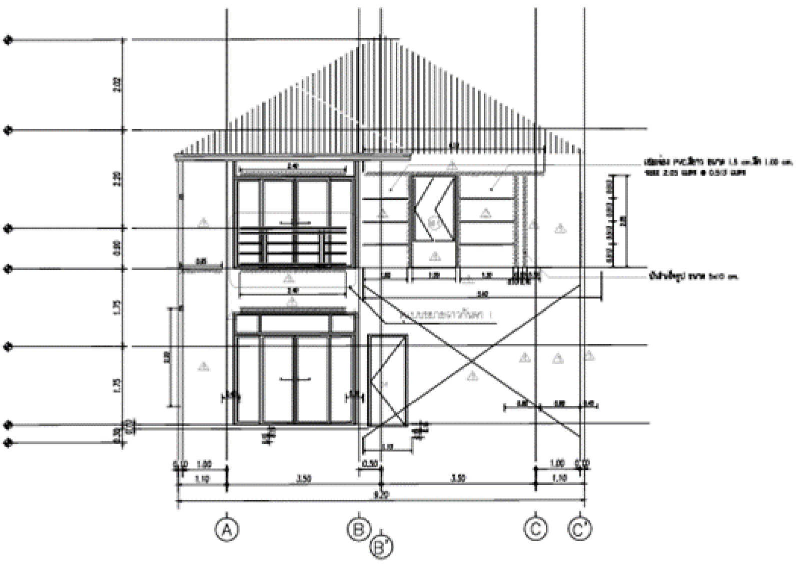

Figure 4. The section view of the case study.

3.3 System preparation

In this study, the resources required to implement the prototype system in the experiment are divided into two parts as follows:

3.3.1 Hardware preparation

The hardware components for developing the prototype system include a laptop and the Head-Mounted Displays (HMDs). This section describes the functionalities of each hardware component as follows:

3.3.1.1 A laptop

A laptop selected for this study is a Lenovo Legion Y520, which was chosen for its specifications. The primary features of Lenovo Legion Y520, as shown in Fig. 5 are that it is powered by 7^{th} Gen Intel ® Core™ processors and up to NVIDIA GTX 1050 graphics card and features premium audio and optional dual drive storage for added speed [13].

Figure 5. Lenovo Legion Y520.

3.3.1.2 Head-Mounted Displays (HMDs)

The primary device used for this study was the Meta Quest 2, an advanced all-in-one VR headset categorized as a Head-Mounted Displays (HMDs). The Meta Quest 2 is one of the most popular Virtual Reality (VR) entertainment headsets developed by Meta Platform Inc., which immerses the user in a completely simulated environment [14]. This device's accessories include a VR headset, two touch controllers, a charging cable, two AA batteries, a power adapter, and a glass spacer. In addition, the advantage of this device is that it allows users to communicate, interact, and share their experiences, as shown in Fig. 6.

Figure 6. Meta Quest 2, an advanced all-in-one VR headset.

3.3.2 Software preparation

3.3.2.1 Autodesk Revit

Autodesk Revit is a widely used Building Information Modeling (BIM) tool in the Architecture, Engineering, and Construction (AEC) industry. It is a virtual model that simulates a building structure, enabling users to visualize its width, height, and depth with impressive realism. This software enhances productivity and accuracy throughout the project lifecycle, from conceptual design and analysis to visualization, fabrication, and construction, as shown in Fig. 7.

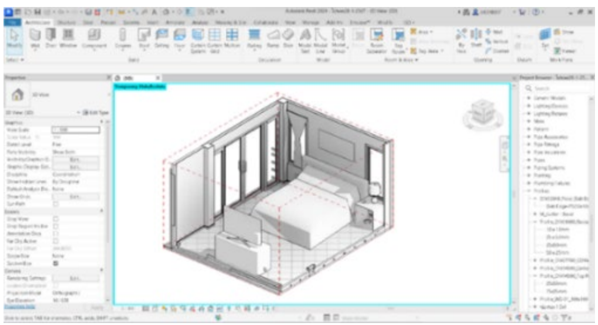

Figure 7. The three-dimensional (3-D) model was created using Autodesk Revit.

3.3.2.2 Enscape

Enscape is a leading visualization tool that creates real-time visualizations and fully rendered 3D walkthroughs that are explorable from every angle. It also offers seamless integration, extensive customization options, and robust collaboration features. Enscape was used as the primary software to render the virtual model of the case study, as shown in Fig.8. Then connect a VR headset as the Meta Quest 2 and get ready to walk or fly through their project [15].

Figure 8 . The virtual model of the case study was rendered using Enscape software.

3.4 Proposed system

3.4.1 BIM authoring

The proposed system was developed and implemented as an application that combines Building Information Modeling (BIM) and Virtual Reality (VR). For this demonstration, the project involved the creation of a highly detailed three-dimensional (3D) architectural model of the building, adhering to a Level of Detail (LOD) 300 using Autodesk Revit 2024 based on as-built drawings. Therefore, bedrooms in the 3D model, which was the virtual model, are the same as physical objects in the real world.

The Level of Detail (LOD) of this study was 300, a model that comprehensively represents a building, including precise details for structural and architectural elements. The structural part includes accurate details of elements such as columns, beams, and floors, while the architectural part features detailed models of windows, doors, walls, and stairs. In addition, each object within the model is defined by its exact size, shape, location, and relevant geometric properties such as dimensions, which are length, width, height, and area [16].

3.4.2 Linking the IFC file and the Enscape software

Enscape was used as the primary software for creating the virtual model and integrating visualization technologies between Building Information Modeling (BIM) and Virtual Reality (VR) in this study, as shown in Fig.9. Additionally, a previously developed method was adopted to link the virtual model, facilitating information integration within the three-dimensional (3-D) model rendering, including the three-dimensional (3-D) model.

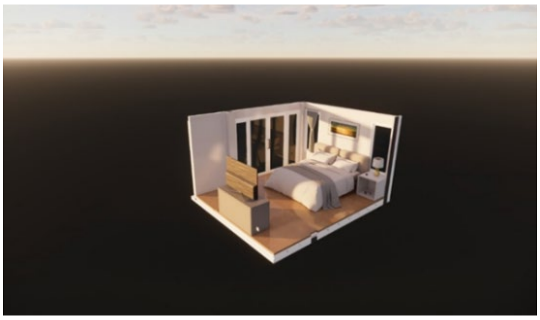

Figure 9. The virtual model in the virtual environment using Enscape software.

3.5 Integration with the Enscape software

The three-dimensional (3-D) model of the case study was viewed in Autodesk Revit 2024 and then imported into Enscape to facilitate the development of virtual environment simulations. This software proved beneficial for creating and rendering high-quality three-dimensional (3-D) models. The details of each process can be explained in the following sub-section.

3.5.1 Integration of Virtual Reality (VR) with the Enscape software

This study developed a proposed system that integrates Building Information Modeling (BIM) and Virtual Reality (VR) to provide the virtual model and allow respondents to perceive and have perception with the virtual model in the virtual environment via Head-Mounted Displays (HMDs), Meta Quest 2 is an advanced all-in-one VR headset that features virtual models in a virtual environment, as shown in Fig.10 assisting homeowners in obtaining information through walkthroughs.

Figure 10. Integration of Virtual Reality (VR) with the Enscape software.

4. Application of the proposed system

This study implemented a proposed system within the Enscape software during the development process. The proposed system provides virtual information through a virtual model of the case study in a virtual environment, with dimensions of bedrooms and the width and height of the physical object in the real world. Similarly, the respondent can navigate and move independently within the virtual environment.

5. The experiment of the proposed system

This study examined the perception measurement through feedback from respondents regarding three types of bedrooms in a nearly completed residential construction project with improper dimensions. The perception of respondents was assessed using Head-Mounted Displays (HMDs) in Enscape software to compare the virtual model with their perception of the physical object at the residential project. Additionally, the questionnaire served as the research instrument to assess the perceptions of respondents in the case study, as shown in Fig.11.

Figure 11. The physical object of the residential project named Icon Project 7 (I-Sport).

5.1 Sample size

The respondents in this study were thirty individuals who were randomly selected to participate in the experiment to facilitate a comprehensive analysis of their preferences regarding bedroom dimensions such as width and height. The primary goal of the experiment was to prove that the perception of the virtual model is similar to the physical object, which can be applied to the residential project to enhance the presentation process.

5.2 Statistical Method

The paired sample t-test is a powerful statistical tool that compares the means of two populations. It involves two samples where each observation in one sample is directly linked or paired with an observation in the other sample, allowing for a more accurate analysis of differences [17]. In addition, the paired sample t-test is a statistical metric tool for estimating if the mean difference between two sets of observational data equals zero [18-21]. Meanwhile, this statistical method examined the differences in the respondents' perceptions of the virtual model and physical object in the residential project. The steps for analyzing the data from the experiment will be provided in the next section.

5.3 Data Collection

The experiment investigated how perception is measured by gathering feedback from respondents regarding three types of bedrooms. This study used Head-Mounted Displays (HMDs) in Enscape software, allowing respondents to view a virtual model and compare it with their perception of the physical object in the residential project. The study hypothesized that the perception of the virtual model would not be different from that of the physical object in the residential project.

In addition, a questionnaire was used as the research instrument to assess the perceptions of the respondents, in the residential project named Icon Project 7 (I-Sport). A five-point Likert scale evaluated the comfort levels of the respondents concerning two dimensions of the bedroom such as width and height. For width, the ratings ranged from 1 (very small) to 5 (very wide), while for height, the ratings ranged from 1 (very low) to 5 (very high), respectively.

5.4 Case Study: Bedroom

In this study, three types of bedrooms were a case study was partitioned into three bedrooms such as 1) the master bedroom, 2) the second bedroom, and 3) the sunny bedroom. In the experimental section, respondents were tested in the three bedrooms in both environments: the virtual model through Virtual Reality (VR) using Head-Mounted Displays (HMDs) and the physical object in the residential project. Then, the respondents gave feedback by scoring their perceptions regarding the dimensions, such as the width and height of the virtual model and the physical object in the questionnaires. Additionally, the scores from their feedback must be analyzed using statistical methods, specifically the paired sample t-test, to demonstrate the differences in the perception of respondents between the virtual model and the physical object in the residential project, as shown in Fig. 12.

(a) (b)

Figure 12. Example of the physical object (a) and the virtual model (b) of the master bedroom

5.5 Data analysis

The feedback from the respondents as the score of their perception between the virtual model and the physical object regarding the dimensions, which were the width and depth of three bedrooms, were analyzed by the paired-sample t-test to obtain the feedback from respondents consisting of the Mean of perception score in the virtual model ($\bar{\mu}_a$) Mean of perception score in the physical object ($\bar{\mu}_b$) Mean of difference score ($\bar{D}_i$), Standard Deviation (S.D.) of perception score by using Eq.(1), Eq.(2), Eq.(3) and Eq.(4) as follows:

$$\bar{\mu}_a = \sum_i^n \frac{X_i}{N} \tag{1}$$

$$\bar{\mu}_b = \sum_i^n \frac{Y_i}{N} \tag{2}$$

$$\bar{D}_i = \sum_i^n \frac{D_i}{N} \tag{3}$$

$$\text{S.D.} = \sqrt{\frac{N\sum_{i=1}^{N} D_i - (\sum_{i=1}^{N} D_i)^2}{N(N-1)}} \tag{4}$$

Where X_i = Perception score of the respondent with the physical object
Y_i = Perception score of the respondent with the virtual model
D_i = Difference score of perception between the physical object and virtual model
N = Number of respondents

Furthermore, in this study, the null hypothesis (H_0) assumes that the mean of the perception score with the physical object ($\bar{\mu}_a$) is not different from the perception of the virtual model ($\bar{\mu}_b$). In contrast, the alternative hypothesis (H_1) assumes that the mean of the perception score with the physical object ($\bar{\mu}_a$) is different from the perception of the virtual model ($\bar{\mu}_b$) with a 0.05 significance level (α = 0.05). Both hypotheses are defined as follows:

$$H_0 : \bar{\mu}_a = \bar{\mu}_b$$
$$H_1 : \bar{\mu}_a \neq \bar{\mu}_b$$

After verifying assumptions and completing calculations, the final step is to determine whether the results are statistically significant enough to reject the null hypothesis and support the alternative hypothesis.

6. Results of the experiment

6.1 Comparison of the difference between the perception of the virtual model and the physical object

6.1.1 Case Study 1: The width of bedrooms

This case study was conducted to evaluate the perceptions of 30 respondents regarding three different types of bedrooms, which focused on the dimensions, precisely the width of the master bedroom, the second bedroom, and the sunny bedroom, using both a virtual model and a physical object for comparison. In addition, the paired sample t-test was used to analyze the difference in perception scores between the virtual model and the physical object regarding the dimension, as the width of each bedroom can be presented in Table 1 to Table 3.

Table 1 The Mean, Standard Deviation of perception score for the master bedroom width (α = 0.05).

Description	
Number of respondents	30
Mean	-0.070
Standard Deviation	0.580
Sig. (2-tailed)	0.536
H_0	Accept
H_1	Reject

Table 1 presents the mean, standard deviation, significance (2-tailed), and hypotheses regarding the perception scores between the virtual model and the physical object representing the master bedroom width. The significant (2-tailed) value obtained was 0.536, higher than the critical value (α = 0.05). Therefore, the null hypothesis is accepted, indicating no significant differences in the perception of the virtual model and the physical object during the presentation process.

Table 2 The Mean, Standard Deviation of perception score for the second bedroom width (α = 0.05).

Description	
Number of respondents	30
Mean	-0.030
Standard Deviation	0.490
Sig. (2-tailed)	0.712
H_0	Accept
H_1	Reject

Table 2 presents the mean, standard deviation, significance (2-tailed), and hypotheses regarding the perception scores between the virtual model and the physical object representing the second bedroom width. The significant (2-tailed) value obtained was 0.712, higher than the critical value (α = 0.05). Therefore, the null hypothesis is accepted, indicating no significant differences in the perception of the virtual model and the physical object during the presentation process.

Table 3 The Mean, Standard Deviation of perception score for the sunny bedroom width (α = 0.05).

Description	
Number of respondents	30
Mean	-0.023
Standard Deviation	0.680
Sig. (2-tailed)	0.070
H_0	Accept
H_1	Reject

Table 3 presents the mean, standard deviation, significance (2-tailed), and hypotheses regarding the perception scores between the virtual model and the physical object representing the sunny bedroom width. The significant (2-tailed) value obtained was 0.070, higher than the critical value (α = 0.05). Therefore, the null hypothesis is accepted, indicating no significant differences in the perception of the virtual model and the physical object during the presentation process.

6.1.2 Case Study 2: The height of bedrooms

This case study was conducted to evaluate the perceptions of 30 respondents regarding three different types of bedrooms, which focused on the dimensions, precisely the height of the master bedroom, the second bedroom, and the sunny bedroom, using both a virtual model and a physical object for comparison. In addition, the paired sample t-test was used to analyze the difference in perception scores between the virtual model and the physical object regarding the dimension, as the height of each bedroom can be presented in Table 4 to Table 6.

Table 4 The Mean, Standard Deviation of perception score for the master bedroom height (α = 0.05).

Description	
Number of respondents	30
Mean	0.030
Standard Deviation	0.720
Sig. (2-tailed)	0.801
H_0	Accept
H_1	Reject

Table 4 presents the mean, standard deviation, significance (2-tailed), and hypotheses regarding the perception scores between the virtual model and the physical object representing the master bedroom height. The significant (2-tailed) value obtained was 0.801, higher than the critical value (α = 0.05). Therefore, the null hypothesis is accepted, indicating no significant differences in the perception of the virtual model and the physical object during the presentation process.

Table 5 The Mean, Standard Deviation of perception score for the second bedroom height (α = 0.05).

Description	
Number of respondents	30
Mean	-0.027
Standard Deviation	0.870
Sig. (2-tailed)	0.103
H_0	Accept
H_1	Reject

Table 5 presents the mean, standard deviation, significance (2-tailed), and hypotheses regarding the perception scores between the virtual model and the physical object representing the second bedroom height. The significant (2-tailed) value obtained was 0.103, higher than the critical value (α = 0.05). Therefore, the null hypothesis is accepted, indicating no significant differences in the perception of the virtual model and the physical object during the presentation process.

Table 6 The Mean, Standard Deviation of perception score for the sunny bedroom width (α = 0.05).

Description	
Number of respondents	30
Mean	-0.030
Standard Deviation	0.600
Sig. (2-tailed)	0.010
H_0	Accept
H_1	Reject

Table 6 presents the mean, standard deviation, significance (2-tailed), and hypotheses regarding the perception scores between the virtual model and the physical object representing the sunny bedroom height. The significant (2-tailed) value obtained was 0.010, higher than the critical value (α = 0.05). Therefore, the null hypothesis is accepted, indicating no significant differences in the perception of the virtual model and the physical object during the presentation process.

7. The cost, time, and resources required to implement the proposed system in actual construction projects

7.1 Comparison of time in implementing the proposed system and the show unit of the case study

This study has to compare the time required to implement the proposed system in each process and the show unit of the case study, as presented in Table 7.

Table 7 The time required to implement the proposed system and the show unit of the case study

Description	Time (man-hr)
The proposed system	
1. Created the 3D model	3
2. Linking the IFC file and the Enscape software	0.5
3. Integration of Virtual Reality (VR) with the Enscape software	0.5
Total	**4**

Table 7 presents the time required to implement the proposed system. The findings indicate that the method combines BIM-based Virtual Reality to create a virtual model of the case study in 4 hours for implementation. In contrast, the traditional construction of the show units of the case study, which was the residential project named Icon Project 7 (I-Sport), required 8 months, which is a significantly faster approach than the conventional method, reducing the lead time before the show unit can be showcased to prospective buyers.

7.2 The detail of cost and resources in implementing the proposed system

This study proposes the cost and resources to implement the proposed system, including the hardware and software costs, as presented in Table 8.

Table 8 Investment cost of the system preparation to implement the proposed system

Resource	Cost (Baht)
Hardware	
1. Lenovo Legion Y520	31,900.00
2. Meta Quest 2	10,342.46
Software	
1. Autodesk Revit	99,871.20
2. Enscape	27,879.63
Total Cost	**169,993.29**

Table 8 presents the investment cost of the system preparation to implement the proposed system. The findings indicate that the total cost was 169,993.29 Baht. Meanwhile, the software cost was calculated based on one year.

Table 9 Operation cost of the system preparation to implement the proposed system

Resource	Cost (Baht/month)
Staff	
1. Salary of BIM modeler	20,000.00
Total Cost	**20,000.00**

Table 9 presents the operation cost of the system preparation to implement the proposed system. The findings indicate that the operation cost was the salary of the BIM modeler position, amounting to 20,000.00 Baht per month.

8. Conclusion

In conclusion, the proposed system is a BIM-based Virtual Reality (VR) that enhances the presentation process by utilizing a virtual model for residential projects. In this case study, an experiment was conducted to compare the perception scores of the virtual model viewed through the Head-Mounted Displays (HMDs) with those of a physical object of the residential project. Thirty respondents participated in the experiment, which measured their perception scores regarding the dimensions of three types of bedrooms: the master bedroom, the second bedroom, and the sunny bedroom at the residential project named Icon Project 7 (I-Sport). The paired sample t-test was used to analyze the differences in perception scores between the virtual model and the physical object. The results indicated that perceptions of the virtual model were not significantly different from the physical object. In addition, the time required to implement the proposed system to create a virtual model of the case study is 4 hours for implementation, which is a significantly faster approach than the conventional method. Additionally, the total cost consisting of investment and operation costs of implementing the proposed system were 169,993.29 Baht and 20,000.00 Baht per month, respectively. Consequently, the ability of these virtual models to effectively simulate physical objects enables residential projects to enhance presentations while reducing project time and expenses.

However, this study has several limitations that should be addressed in future research. One key limitation is that the proposed system only presents virtual information through Head-Mounted Displays (HMDs). Therefore, if respondents are not using Head-Mounted Displays (HMDs), they will not be able to access the virtual information provided by the system. In the future, more visualization technologies will be integrated into the proposed system, including CAVEs and HoloLens, to provide virtual information for residential projects.

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