Development of an AR Site Visualization Application to Enhance User Experience for Integrating Conceptual House Design into Real Environments

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Abstract **The rapid development of immersive technology, particularly Augmented Reality (AR), has significantly supported the digitization of infrastructure in the Fourth Industrial Revolution. In the property industry, conventional visualization media such as two-dimensional (2D) floor plans are often difficult for non-technical users to interpret. By focusing on the conceptual design phase to enhance user experience, an area often overlooked in prior research that emphasizes marketing, this study develops an Android-based application, AR Site Visualization, that converts 2D floor plans into interactive three-dimensional (3D) models in real time. The development applied the six-stage Multimedia Development Life Cycle (MDLC) framework, supported by Unity, Vuforia SDK, and Lean Touch for feature integration. The 3D models were created using SketchUp and Enscape to ensure realistic visualization. Evaluation through Black Box Testing and formative assessments demonstrated that all features, including marker scanning, 3D visualization, rotation, zoom, and translation, worked effectively, achieving a feasibility score of 71.5%. The results indicate that AR Site Visualization enhances spatial understanding and improves design communication for users.**

Key words: **Augmented Reality, Multimedia Development Life Cycle, 3D Visualization, Real Estate, Unity.**

I. INTRODUCTION

The development of immersive technologies, including Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR), has shown significant growth in recent decades, changing the way humans interact with digital information through the integration of the real and virtual worlds [1]. Among these technologies, AR has the advantage of maintaining the context of the real environment while adding an interactive digital layer [2], making it a key driver of infrastructure digitization in the Fourth Industrial Revolution, particularly in the design and construction sectors [3][4]. The effectiveness of AR in improving spatial understanding has been proven in various applications, ranging from evacuation route simulations [5][6] to the visualization of complex architectural designs [7].

The application of AR has expanded to various fields, such as civil infrastructure [8], education [9], and the simulation of human behavior during disasters [10]. However, one of the sectors that has been most significantly impacted is real estate [11]. The property industry was chosen as the focus because the process of buying a house often involves high-risk decisions, where prospective buyers need the clearest possible picture [12]. Research consistently shows that AR can improve customer experience, strengthen property visualization, and effectively build consumer trust [13][14].

Despite these advantages, current AR research in real estate and architecture has predominantly focused on marketing and promotional visualization [12][13], while studies on design comprehension exist but remain limited to general architectural contexts [7]. Few have specifically addressed the use of AR in the conceptual design phase of residential houses, where usability and user experience are critical for decision-making. The communication gap between two-dimensional (2D) floor plans and users three-dimensional spatial perception remains a key challenge [11][15].

To strengthen problem identification, researchers conducted a preliminary survey of 22 potential app users. The survey results showed that 68.2% of respondents had experience using AR apps, while 31.8% had never used them. This finding indicates that most respondents are already familiar with AR technology. However, the main challenge lies in understanding 2D house plans. As many as 77.3% of respondents admitted to having difficulty understanding 2D house plans or conceptual designs, while only 22.7% did not experience any difficulties. This data confirms the communication gap between 2D floor plan representations and users' spatial perceptions, which is one of the main reasons why the development of AR applications is important in this study.

To achieve these objectives, this study adopts the Multimedia Development Life Cycle (MDLC) method, which provides a systematic six-stage process for designing, developing, and evaluating multimedia applications[16]. The MDLC framework was chosen because it emphasizes iterative development and usability testing, ensuring that the application not only functions technically but also meet user-centered design requirements.

Therefore, this study aims to develop and evaluate an application called "AR Site Visualization," designed to transform 2D house plans into interactive 3D models accessible via mobile devices. This application seeks to enhance user understanding of conceptual designs and provide practical solutions that integrate AR into the early design stages of housing projects. The novelty of this research lies in its focus on the conceptual design phase with an emphasis on usability and user-centered experience, supported by the integration of Unity, Vuforia, and SketchUp–Enscape within the Multimedia Development Life Cycle (MDLC) framework.

II. Literatur Review

Augmented Reality (AR) is a technology whose function is to enhance perception of the user by bringing virtual information into the real world interactively and in real time[17]. The innovation of AR in the Fourth Industrial Revolution has triggered infrastructure digitization, particularly at architectural and construction levels where accurate space visualisation is essential. AR is also increasingly becoming a strategic design and construction tool, although adoption and integration barriers remain significant[4]. Xu and Moreu [3] highlight that the utilisation of AR in civil infrastructure is not only visualisation but also a medium through which data-driven decision-making may be attained.

Previous research has it that the effectiveness of AR is never entirely determined by the level of technological sophistication but is very much reliant on the approach methodologically. Ramli et al. [9], for instance, argue on the need to adopt a systematic and well-defined method of development so that the prototypes of AR will truly function at their optimum. This is an indication of the gap between the technological promise of AR and its usage in practical contexts. Following the same trend is Ampatzoglou et al. [18], where architectural decisions are treated as capital investments whose costs and rewards need to be examined and where usability is paramount. As a result, the user experience now forms the overriding foundation in developing applications of AR.

Osorto Carrasco and Chen [7] demonstrate mixed reality to be very effective in improving architectural design comprehension effectiveness, while Parman et al. [12] and Aher et al. [13] argue that AR is not only visually attractive but also facilitates decision-making by building client trust through real-world simulation. For architecture and real estate areas, AR has been discovered to be capable of addressing the fundamental issue of the cognitive gap between design representation in two-dimensional (2D) and client perception of space. Most of these studies, however, emphasise the context of design communication or market communication, while only a few apply them to the conceptual design stage. Castro Pena et al. [19], in their literature review of how architectural design in a conceptual context has been applied using artificial intelligence (AI), encapsulate the essence of how technology must be explored in the initial design stages. However, their focus is on AI and not on AR and so the space exists to investigate an optimum application of how to utilize AR in the architecture conceptual stage.

The application of recent AR software is dependent on the right software support. Unity is a perfect illustration in this regard because it is flexible in integrating several Software Development Kit (SDKs) and 3D assets [14]. SDKs such as Vuforia possess fine marker detection capabilities upon which Sharma et al. [5] deem it essential to develop adequate spatial knowledge. From the modelling's perspective, the workflow from SketchUp [20] to Enscape [21] is a strategic choice, as SketchUp offers design effectiveness while the photorealistic characteristic of Enscape raises user acceptability. The selection of this technology combination points to the requirements to balance effectiveness in developing it with excellence in the resultant user experience.

For sustained focused AR application development, a systematic methodological approach is required. The Multimedia Development Life Cycle (MDLC) was chosen because it has been used to develop highly complex multimedia projects such as AR [16]. One of the main advantages of MDLC is its ability to integrate disparate media assets (user interfaces, 3D objects) into a coherent workflow from concept design to distribution [22]. Unlike other approaches, MDLC emphasises iterative testing at each stage, making it highly relevant to AR applications where usability is the prime success determinant. Jalali [23], in a bibliometric analysis in Computers in Human Behavior, revealed that the global trend in human-computer interaction increasingly prioritises user experience, justifying the mandate of this study to design truly user-centric AR applications.

Beyond Indonesian studies that frequently adopt MDLC, several international works have introduced alternative methodological approaches for AR development. Zamora-Antuñano et al. [24] proposed the MeDARA methodology, which structures AR projects through analysis, design, implementation, testing, and deployment. Hussien et al. [25] presented ARGILE, an agile-based framework that improves communication and project delivery, while Ankora and Aju [26] demonstrated the use of SCRUM practices such as user stories and personas to strengthen user-centered design. These approaches highlight a global trend toward agile and flexible development models, although in this research MDLC is selected for its structured asset integration and systematic usability validation.

A few prior studies have investigated the use of AR and MR across different domains, ranging from disaster evacuation to real estate visualization. Table 1 summarizes several representative works, highlighting their application contexts, main contributions, and limitations. This comparison shows that while AR has been widely applied, research specifically targeting the conceptual design phase of residential houses with a focus on usability remains limited.

TABLE I. SUMMARY OF RELATED AR/MR STUDIES.

Author(s)	Title	Contribution	Limitation
Sharma et al. [5]	Emergency Response Using HoloLens for Building Evacuation	Developed AR app with 3D interactive evacuation routes, improved spatial understanding	Limited to evacuation, no relevance to real estate
Manfredi et al. [6]	A Mixed Reality Application for Multi-Floor Building Evacuation Drills	Created MR app with dynamic pathfinding and real-time 3D modeling	Only tested for evacuation drills, not architectural use
Lovreglio [10]	Virtual and Augmented Reality for Human Behaviour in Disasters: A Review	Provided comprehensive review of AR/VR for disaster simulations	Did not propose specific applications in architecture/real estate
Aher et al. [13]	Augmented Reality in Real Estate: Enhancing Property Visualization and Customer Experience	Showed AR enhances customer satisfaction and accelerates purchase decisions	Did not detail technical implementation
Patel et al. [14]	Realar: Integrating AR and 3D Models for Real Estate Platforms	Enabled interactive mobile-based visualization of 3D house models	Early prototype, limited user evaluation

As shown in Table I, previous studies have mainly applied AR/MR for evacuation and disaster simulations[5][6][10] or for marketing-oriented real estate applications[13][14]. While evacuation-related studies contributed to spatial awareness and safety, their scope remains limited to emergency contexts and lacks relevance for architectural visualization. Similarly, real estate applications positioned AR primarily for buyers and sellers, focusing on promotional appeal rather than usability. In contrast, this study develops an AR Site Visualization application with a broader perspective on user experience, supporting diverse stakeholders such as architects, designers, developers, and students. By applying the MDLC framework and emphasizing interactivity features, the research fills a gap between 2D plans and 3D spatial understanding in conceptual house design.

III. RESEARCH METHODOLOGY

This study employs the Multimedia Development Life Cycle (MDLC) framework as the development method. MDLC was selected because it provides a structured workflow for multimedia integration and emphasizes iterative testing, which is critical for ensuring usability in AR applications. The developed system is an Android-based AR application that visualizes 2D house plans into interactive 3D models. Users can scan the floor plan marker with their mobile device to display the 3D model in real environments and interact with it through rotation, translation, and scaling.

The application development process follows the six main stages in MDLC, as shown in Fig. 1.

Fig. 1. Multimedia Development Life Cycle (MDLC)[27]

A. Concept

The initial stage involves identifying problems and formulating research objectives. A preliminary survey with random participants revealed that many users found conventional 2D floor plans difficult to interpret, often leading to miscommunication in understanding spatial layouts. This observation is consistent with previous studies [13][15][28], which also highlight the limitations of 2D media. Therefore, the objective of this study is to develop an AR application that converts 2D floor plans into interactive 3D visualizations, providing users with a more realistic and intuitive understanding of house designs.

B. Design

In the design stage, storyboards were created to define the main menus, navigation flow, and interaction features such as rotation, zoom, and object cutting. The user interface (UI) was designed to prioritize usability, so that users could easily access functions with minimal learning effort. Unity was selected because of its flexibility in integrating AR SDKs such as Vuforia[7][14].

C. Material collecting

At this stage, the necessary digital assets were collected, including a 3D model of the house created using SketchUp and rendered with Enscape, markers in the form of 2D floor plans from housing brochures/websites, and UI elements created with Canva. The Lean Touch interaction library from the Unity Asset Store was also used to support the zoom and move functions, with logic from C# scripts for rotation using the D-Pad buttons as shown in Table. II.

TABLE II. LIST OF REQUIRED ASSETS

Asset Type	Source/Software	Format
3D model	SketchUp dan Enscape	.FBX
Marker	Residential Website	.JPG
UI	Canva	.PNG
interaction library	Lean touch (Unity Asset Store)	Script C#
3D Render Images	SketchUp and Enscape	.PNG

These assets were selected to support the functionality and usability of the AR Site Visualization application. The 3D house model was created using SketchUp and rendered in Enscape, then exported in .FBX format to ensure compatibility with Unity. Markers in .JPG format were obtained from a residential website to represent 2D floor plans that could be easily recognized by Vuforia SDK. The user interface (UI) was designed in Canva and stored in .PNG format to allow lightweight integration. For interaction, the Lean Touch library from the Unity Asset Store was employed to provide intuitive rotation, zoom, and translation gestures without developing complex scripts from scratch. Custom behaviors were implemented through C# scripts to connect AR features with user interactions. Finally, 3D rendered images from SketchUp and Enscape were included as .PNG files to provide additional visualization support for evaluation and comparison.

D. Assembly

All assets are integrated using Unity as the main game engine. Unity was chosen for its flexibility in supporting various platforms, ease of integration with Software Development Kits (SDKs), and large developer community, which facilitates problem solving[29]. 3D models created using SketchUp and Enscape are exported in FBX format for compatibility with Unity, then imported into the project. The FBX format was chosen because it can retain geometric details while being compatible with Unity's rendering features.

To support visual detection, the Vuforia SDK is used. This component functions as a marker recognizer in the form of a 2D house plan that is used as an image target. When the mobile device's camera is pointed at the marker, Vuforia automatically recognizes the image pattern and displays the 3D model on top of it in real-time. Vuforia's computer vision technology has proven to have a high level of stability even in suboptimal lighting conditions, ensuring smooth user interaction.

In addition to displaying models, user interactivity is an important part of the creation stage. For this purpose, the Lean Touch library, downloaded from the Unity Asset Store as shown in Fig. 2, is used. Lean Touch enables the integration of touch gestures on the device screen, such as rotation with one finger, translation (moving objects) with two fingers, and zoom in/out using the pinch technique.

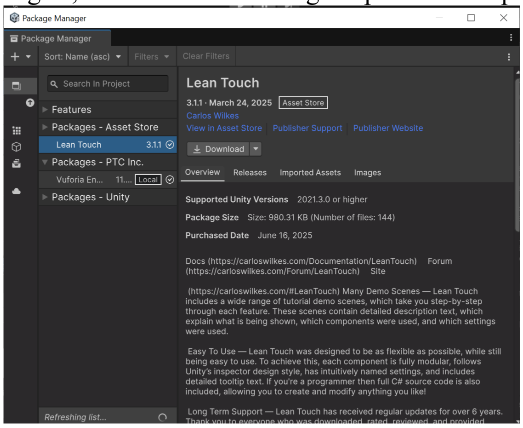


Fig. 2. Library Lean Touch

At this stage, programming is also carried out to ensure that all features are working properly. The programming language used is C# as shown in Fig. 3, it is Unity's native language and supports cross-platform application development. Each application function, such as rotation commands with the D-Pad buttons, navigation between menus, and section views, is created in the form of separate scripts to make them more modular and easier to manage. This modular approach also facilitates maintenance and the development of additional features in the future.

Fig. 3. Some C# code

E. Testing

Testing was conducted using the Black Box Testing method, focusing on testing the functionality of the application (e.g., marker detection, 3D model rendering, and user interaction). In addition, limited trials were conducted with users to evaluate usability and visualization quality. Success criteria included: The application was able to display 3D models according to markers, rotation, zoom, and navigation interactions ran smoothly, and users felt assisted in understanding the house design.

In addition to functional testing using the Black Box Testing method, this study also conducted beta testing to evaluate the usability and user satisfaction aspects of the AR Site Visualization application. Beta testing was conducted by involving a limited number of users who represented potential end users. The aim was to identify practical problems in the application. Lallemand et al. [30] emphasized that user evaluation is a crucial stage in the development of interactive applications because it provides a direct picture of the user's experience and needs.

In this study, trials were conducted on 22 respondents from the general public to carry out formative evaluation. The main objective of this evaluation, in line with what was described by Sauro and Lewis [31], was to find problems and weaknesses in the application as a basis for improvement before further development. The evaluation instrument used was a questionnaire with a 1–5 Likert scale covering aspects of ease of use, 3D visualization quality, interactivity, and user satisfaction.

Although formative evaluations are often qualitative in nature, Sauro and Lewis [31] state that quantification can still be done to reinforce findings. The use of quantitative metrics from questionnaires in this study aims to provide objective data on user perceptions of the application's functionality.

F. Distribution

The final stage is compiling the application into .APK format for Android devices. The application is tested on devices with mid-range specifications to ensure compatibility. Distribution is carried out via cloud-based storage (Google Drive) to facilitate further evaluation.

By following these six MDLC stages, the developed AR application is expected to provide a solution to the limitations of 2D floor plan visualization and enhance the user experience in understanding home architectural designs.

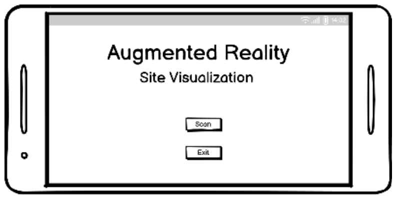
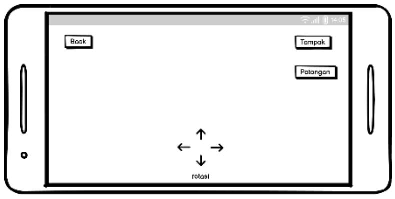
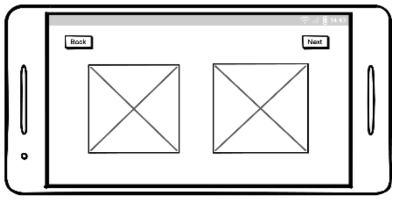
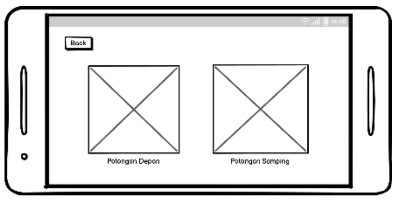
IV. Result And Discussion

A. Application implementation results

The AR Site Visualization application was developed following the six stages of the Multimedia Development Life Cycle (MDLC), consisting of Concept, Design, Material Collecting, Assembly, Testing, and Distribution as shown in Fig.1. In this section, the focus is on the complete development process from Concept to Distribution.

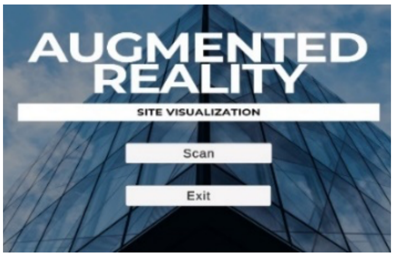
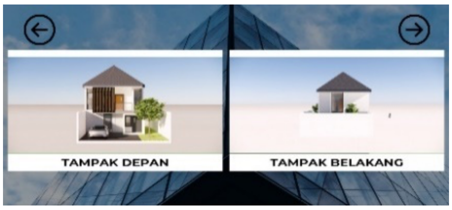
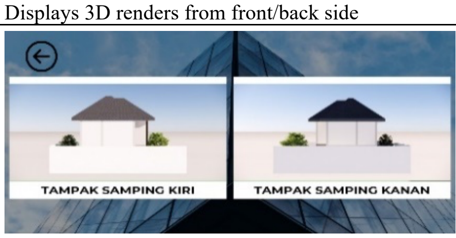
During the Concept stage, the objectives of the application and user requirements were defined, aiming to provide an interactive AR experience that enhances spatial understanding of house designs. In the Design stage, the user interface and interaction flow were planned, guided by the storyboard presented in Table III, which illustrates the sequence of screens and expected user interactions, providing a comprehensive blueprint that ensured the development could implement features consistently. By detailing the planned navigation and interaction patterns, the Design stage helped prevent usability issues during later implementation and served as a reference for both developers and evaluators during testing.

TABLE III. AR Site Visualization Storyboard

Scene	UI/Description
Main Menu	 Initial view of the application with title and scan button, exit
Scan Menu	 Active camera to detect markers and bring up objects as well as view/cut and rotation buttons
Visible Menu	 The result is a render image of a 3D object from the left/right and front/back side
Cut Menu	 A 3D rendered image of a cropped object

The Material Collecting stage involved gathering all necessary digital assets, including 3D house models developed in SketchUp and Enscape and exported to FBX format for Unity compatibility, along with textures, icons, and UI components. In the Assembly stage, these assets were successfully integrated into Unity, with Vuforia SDK enabling marker detection and Lean Touch supporting interactive features such as rotation, zooming, and translation. Table IV summarizes the implementation results, showing that all core functionalities were integrated successfully, and the application interface was designed to be simple and intuitive for users.

TABLE IV. APP RESULTS DOCUMENTATION

Scene	UI/Description
Main Menu	 Main page with scan and exit buttons
Scan camera	 Starting the camera for scan markers
AR Display	 Appear 3D objects from markers that have been scanned with the D-Pad button for rotation, pinching, moving with 2 fingers, visible and cut
The user uses the rotation/zoom/move function	  Rotate/enlarge/shrink/shift model according to command
View Menu 1	 Displays 3D renders from front/back side
View Menu 2	 Displays a 3D rendered image of an object from the left/right side
Cut Menu	 Displays 3D rendered images to see the inside of objects from the front/side side

B. Application testing

Alpha testing was conducted offline by the developer through black box testing on an Android device to verify the functionality of all features. The test results are shown in Table V.

TABLE V. BLACK BOX TEST RESULTS

Feature	Test Details	Conclusion
Main menu	Selecting the scan button	Succeed
	Selecting the exit button	Succeed
Scan marker	Camera tracking against markers	Succeed
Display 3D objects	Compatibility of 3D objects with markers	Succeed
Menu scan	Select the view menu	Succeed
	Selecting the cut menu	Succeed
	Using the rotation button	Succeed
	Pinch 3D objects to zoom in/out	Succeed
	Using 2 fingers to move objects	Succeed
Menu view	Selecting the next button	Succeed
	Selecting the back button	Succeed
Cut menu	Selecting the next button	Succeed
	Selecting the back button	Succeed

Beta testing was conducted online with random participants. in the Distribution stage, the Application Package Kit (APK) was distributed via Google Drive, and respondents were asked to provide feedback through a Google Form containing screenshots of the application interface and questions regarding usability and user experience. Since the testing was done remotely, the researcher could not fully control whether participants installed the APK or only relied on the screenshots, but their responses still provided valuable insights into the clarity of the interface and perceived usefulness of the features. A total of 22 respondents participated, with each session lasting approximately 10-15 minutes. The results of their assessment are summarized in Table VI.

TABLE VI. APPLICATION BETA TEST RESULTS

Assessment aspects	Average score (1-5)	Description
Main menu view	3.7	Good, can be used, but there are still many shortcomings
3D model view with interaction buttons	3.7	Good, can be used, but there are still many shortcomings
View render view and crop	3.6	Good, can be used, but there are still many shortcomings

Methodologically, this test was designed as a formative evaluation, with the main objective of identifying the strengths and weaknesses of the application. According to Sauro and Lewis [31], a sample size of 22 respondents is very strong for a formative study, as it far exceeds the minimum number (below 10) considered valid for identifying the most common usability problems. This number of respondents is not only effective for finding problems but also provides greater stability to the quantitative data collected. This feasibility score of 71.5%, along with qualitative input, successfully shows which areas are functioning well and which areas need improvement, in line with the main objectives of formative evaluation. These findings are also consistent with Aher et al. [13] and Patel et al. [14], who emphasized that the integration of AR and 3D models increases realism and supports more informed decision-making.

C. Discussion

Although the implementation results show good performance, there are several technical limitations that need to be noted. One of them is the application's dependence on the quality of the mobile device's camera. On devices with low camera resolution, the marker tracking process tends to be less stable, causing the 3D model to not appear accurately. This condition is in line with the findings of Ramli et al. [9], who stated that hardware quality is a determining factor in the success of Augmented Reality applications. Therefore, testing on various levels of device specifications is important to ensure that the application can be widely used by people with different economic capabilities.

In addition, the results of this study reinforce the study by Patel et al. [14], which emphasizes the importance of integrating Augmented Reality with 3D models to enhance visual appeal and interactive experiences. However, unlike Patel's research, which focused on web-based platforms, this study adopted an Android-based approach to maximize user mobility and accessibility. Thus, the developed application not only functions as a static visualization medium but also provides a real-time interactive experience that is more suited to modern marketing needs.

The use of Unity and Vuforia SDK proved effective in supporting application stability, in line with Sharma et al.'s [5] research showing the effectiveness of AR devices in improving spatial understanding. Meanwhile, the application of MDLC in the development process also successfully guided this research systematically, in accordance with Aryani et al.'s [16] findings that MDLC is effective in the development of AR-based multimedia applications.

When compared with other development methodologies, the adoption of MDLC proved advantageous because of its structured and iterative testing stages. While agile methods such as SCRUM and ARGILE provide flexibility and faster prototyping cycles [25][26], they do not explicitly emphasize the systematic integration of multimedia components, which is critical for AR applications where 3D assets, textures, and user interactions must be managed consistently. By contrast, the MDLC framework explicitly incorporates testing and validation at each stage, ensuring that usability issues are identified early in the process. This aligns with Börsting et al. [32], who stressed the necessity of life-cycle–based frameworks in delivering quality AR systems.

Thus, the AR Site Visualization application is not only technically successful but also has practical contributions in improving user experience and minimizing miscommunication between clients and developers, as emphasized by Putra [15]. For architects and designers, the application serves as a powerful communication tool to gain faster client approval, reducing costly revisions during later stages. For prospective home buyers (clients), it demystifies complex floor plans, empowering them to make more informed and confident purchasing decisions. For real estate developers, this tool can enhance marketing efforts by offering an immersive experience that traditional brochures cannot match.

V. CONCLUSION AND SUGGESTION

A. Conclusion

This study successfully developed an Android-based AR Site Visualization application using the MDLC framework. The application transforms 2D house plans into interactive 3D models in real time, supported by Unity, Vuforia SDK, and Lean Touch. Usability testing through Black Box confirmed that all core features marker scanning, rotation, zooming, translation, and sectional views were functioning correctly. Beta Testing with 22 respondents yielded an overall usability score of 71.5%, indicating that the application is generally effective and user-friendly. Theoretically, this research contributes to the knowledge of AR in architectural design by demonstrating that structured development methodologies can address usability challenges effectively. Practically, the application enhances spatial understanding, strengthens communication, and reduces misinterpretation during design decision-making users.

For further research, it is recommended to re-examine performance across diverse device specifications, refine usability based on user feedback, incorporate additional interactive features, and conduct longitudinal studies to assess user learning and engagement over time.

B. Suggestion

Despite the promising results, several areas remain open for further development. First, advanced interaction features, such as detailed room-level exploration and customizable house sections, could increase the depth of visualization. Second, performance optimization on low-specification devices is essential to ensure equitable accessibility across diverse user groups. Third, a broader usability evaluation involving not only students, but also professional architects, developers, and potential homeowners would provide more comprehensive feedback and external validity. Finally, future research should explore integration with emerging technologies, such as Building Information Modeling (BIM) for design interoperability, Internet of Things (IoT) for real-time environmental simulation, or hybrid development methodologies that combine the structured nature of MDLC with the flexibility of agile approaches like SCRUM [25][26]. Such extensions could further enhance both the academic contribution and practical impact of AR in the real estate and architectural design industries.

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