International Journal of Computer and Information System (IJCIS)
Peer Reviewed – International Journal
Vol : Vol. 07, Issue 03, August 2026
e-ISSN : 2745-9659
https://ijcis.net/index.php/ijcis/index

Development and Usability Evaluation of an Android-Based Marker-Based Augmented Reality Application for Residential Property Promotion

Devi Afriyantari Puspa Putri*1, Endah Sudarmilah2, Fatah Yasin Al Irsyadi 3, Zildan Alfatih Agustian 4, Alif Pandu Raharjo5
1,2,3,4,5 Informatika, Fakultas Komunikasi dan Informatika, Universitas Muhammadiyah Surakarta
1,2,3,4,5 Surakarta, Indonesia
1 deviapputri@ums.ac.id, 2 endah.sudarmilah@ums.ac.id, 3 fatah.yasin@ums.ac.id, 4l200210109@student.ums.ac.id,
5l200210050@student.ums.ac.id

Abstract— *The growing demand for interactive digital marketing has encouraged the adoption of Augmented Reality (AR) to address the limitations of conventional property promotion media. However, previous studies have mainly focused on system implementation or marketing outcomes, with limited attention to application functionality and user acceptance. This study developed an Android-based marker-based AR application for residential property promotion and evaluated its functionality and usability. The novelty lies in integrating printed property brochures with interactive three-dimensional visualization and combining functional verification with evaluations from public users and property developers. The application was developed using the adapted Four-D (4D) model, Unity, and the Vuforia SDK. Black-box testing was conducted to verify its functionality, while user evaluation involved 51 purposively selected respondents, comprising 45 public users and six property developers. All tested features operated according to the specified requirements. The evaluation instrument satisfied the validity criterion and obtained a Cronbach's Alpha coefficient of 0.678, indicating moderate internal consistency that was considered adequate for this exploratory evaluation. Overall scores of 85.11% from public users and 85.33% from property developers indicated positive user acceptance. These findings support the application's functional correctness and positive user perception under the study conditions, rather than its effectiveness in real-world property marketing.*

Keywords *: Augmented Reality, Residential Property Promotion, Marker-Based, Android Application, Usability Evaluation..*

I. INTRODUCTION

Digital transformation has changed how companies communicate product information and interact with prospective customers. Digital platforms are increasingly used not only to expand promotional reach but also to provide information that is accessible, engaging, and easier to understand throughout the decision-making process [1–5]. Augmented Reality (AR) supports this development by overlaying virtual objects onto the real-world environment in real time through devices such as smartphones and tablets [6–9]. Its ability to present three-dimensional objects from multiple viewing angles makes AR particularly relevant for products whose physical and spatial characteristics are difficult to communicate through conventional media.

This need is evident in residential property promotion. Prospective buyers require more than information about prices and building specifications; they also need to understand building forms, spatial layouts, room arrangements, and relationships between spaces. However, property promotion still commonly relies on printed brochures, photographs, videos, and physical scale models. Printed brochures and photographs provide only two-dimensional representations, which may make it difficult for prospective buyers to understand the overall spatial characteristics of a property. Physical scale models offer better spatial representation but involve relatively high production costs, require storage space, and are difficult to modify when building designs change [11–13]. The specific problem is therefore how to provide prospective buyers with a more interactive and comprehensible property visualization without removing the accessibility and familiarity of printed promotional materials. Marker-based AR offers a possible response to this problem. Images printed in property brochures can function as markers that trigger three-dimensional building models through an Android smartphone camera. This approach allows prospective buyers to examine a property model from different viewing angles while developers continue using existing brochures as promotional media [11–13]. The specific problem is therefore how to provide prospective buyers with a more interactive and comprehensible property visualization without removing the accessibility and familiarity of printed promotional materials.

Marker-based AR offers a possible response to this problem. Images printed in property brochures can function as markers that trigger three-dimensional building models through an Android smartphone camera. This approach allows prospective buyers to examine a property model from different viewing angles while developers continue using existing brochures as promotional media [13–15]. Nevertheless, the successful display of a three-dimensional model does not necessarily indicate that an AR application is easy to navigate, comfortable to use, or capable of presenting property information clearly. Application functionality and user acceptance must therefore be evaluated alongside technical implementation.

Previous studies have demonstrated the potential of AR in property promotion but have adopted different evaluation priorities. Setyadi and Ranggadara [14] developed a marker-based AR property catalog, while Ambre et al. [15] implemented an AR-based digital property brochure. Both studies demonstrated the technical feasibility of presenting three-dimensional property models, but their evaluations gave limited attention to application usability and user interaction. Ibrahim et al. [11] examined the relationship between AR-based promotion and prospective buyers' purchase intention, whereas Deep et al. [10] investigated the role of immersive technologies in supporting property-purchasing decisions. Sekar et al. [13] further highlighted AR as an alternative to physical scale models. These studies provide important evidence regarding AR implementation, visualization, and marketing-related outcomes, but they do not consistently evaluate both the functional correctness of the application and its quality from the users' perspective. Table 1 summarizes the focus, evaluation method, and remaining limitations of representative studies on AR-based property promotion.

Table 1.

Study	Research Focus	Evaluation Method	Research Gap
Setyadi & Ranggadara [14]	AR property catalog	Functional testing	Did not evaluate application usability
Ambre et al. [15]	AR-based digital property brochure	Prototype implementation	Limited user-centered evaluation
Ibrahim et al. [11]	Property promotional media	Purchase intention analysis	Focused on marketing outcomes rather than application quality
Sekar et al. [13]	Sustainable property promotion	System implementation	Did not investigate user experience
Deep et al. [10]	Property purchase decision support	Consumer perception	Did not evaluate application usability
This study	Interactive property promotional application	*Black-box testing and usability evaluation*	Develops and comprehensively evaluates application quality from the users' perspective

As shown in Table 1, the research gap concerns the limited integration of technical verification and user-centered evaluation in brochure-based AR property applications. Existing studies generally focus on system implementation, visualization benefits, or marketing outcomes [10–15]. Comparatively less attention has been given to whether the main application functions operate consistently and how intended users perceive its interface, marker recognition, three-dimensional visualization, information quality, performance, ease of use, and promotional benefit. This gap is important because a technically operational AR application may still have usability problems that restrict user acceptance and future adoption [16]. To address this gap, the present study develops an Android-based marker-based AR application that combines printed property brochures with interactive three-dimensional building visualization. The novelty of the study does not lie solely in using marker-based AR, which has been implemented in previous research. Rather, it lies in the integrated development and evaluation approach that combines brochure-based AR visualization, repeated black-box functional verification, and user evaluation involving two relevant stakeholder groups: public users and property developers. This approach provides complementary evidence about the application's functional correctness and user acceptance without assuming that these measures establish real-world marketing effectiveness. Accordingly, this study has three objectives:

1. To develop an Android-based AR application that uses printed property brochures as markers for displaying interactive three-dimensional building models.
2. To verify the functionality of the application through repeated black-box testing against predefined functional requirements.
3. To evaluate the application from the users' perspective using a validated application-specific instrument.

This study contributes an implementation of mobile AR that supplements, rather than replaces, conventional printed property brochures. It also presents an evaluation approach that connects application development with functional verification and user assessment. The findings are expected to provide a reference for future studies on AR-based promotional applications while identifying aspects that require further evaluation across different devices and real-world property marketing environments

II. RESEARCH METHODS

2.1 Research Framework

This study employed a Research and Development (R&D) approach to develop an Android-based AR application for property promotion and evaluate its functional correctness and user acceptance. The development process followed the Four-D (4D) model, consisting of Define, Design, Develop, and Disseminate stages [17–21].

The 4D model was selected because its stages correspond directly to the research objectives and expected outputs. The Define stage supports the identification of user needs and functional requirements; the Design stage translates those requirements into the application architecture, interface, AR markers, and three-dimensional models; the Develop stage integrates implementation with functional and user evaluation; and the Disseminate stage supports research documentation and reporting. This structure enables the application to be developed and evaluated within a single framework.

Compared with the Waterfall model, which primarily organizes software development through sequential technical phases, the 4D model provides a more explicit connection between needs analysis, product design, development, and evaluation. Agile methods are more appropriate for projects requiring continuous delivery and repeated collaboration within a development team, while prototyping models primarily emphasize iterative refinement of an initial prototype. The present study did not focus on continuous software releases or commercial product deployment. Instead, it required a structured process that linked identified user needs with application design, implementation, functional verification, and user evaluation. For these reasons, the 4D model was considered more suitable for the scope and objectives of the study.

Although the 4D model was originally developed for educational products, it was adapted in this study to an AR software-development context. The adaptation retained the four principal stages but adjusted their activities and outputs to address application requirements, AR design, software implementation, functional testing, and user evaluation. Figure 1 presents the overall research workflow.

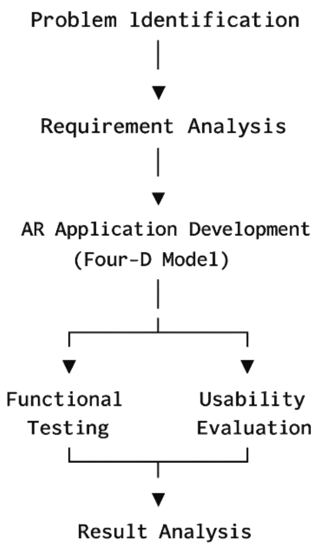

Figure 1. Research Workflow

The implementation of the adapted Four-D model in this study is summarized in Table 2.

Table 2. Implementation of the 4D Development Model

Phase	Activities	Output
Define	Analysis of conventional property promotion limitations, identification of user needs, and specification of functional and system requirements	User and System requirement specifications
Design	Application architecture, navigation structure, user-interface design, storyboard preparation, AR marker design, and three-dimensional property modelling.	Application design and AR Prototype Specifications
Develop	Development of the Android-based AR application Functional testing using the black-box testing method Usability evaluation	Functional AR application Functional testing results Usability evaluation data
Disseminate	Documentation and preparation of the research article	Scientific publication

During the Define stage, the limitations of conventional property promotion media were examined to identify the information and visualization needs of prospective users. These needs were converted into system requirements, including menu navigation, marker recognition, three-dimensional property visualization, property information display, user guidance, and application termination. During the Design stage, the identified requirements were translated into the system architecture, navigation structure, user interface, storyboard, AR marker design, and three-dimensional property models. Design decisions were made to maintain a simple interaction flow for first-time users while ensuring that the main property information and visualization features could be accessed directly. The Develop stage involved implementing the application using Unity and the Vuforia Software Development Kit. The AR markers were integrated with the corresponding three-dimensional building models, and the implemented functions were verified using black-box testing. Seven functional test cases were performed three times by the application developer using the same Android smartphone and application build. A function was classified as valid only when its observed response matched the expected result in all three repetitions. User evaluation was conducted after functional verification. Participants were selected using purposive sampling because the study required perspectives from two relevant stakeholder groups: prospective public users and property developers. The main evaluation involved 51 participants, comprising 45 public users and six property developers. Each participant used the same Android smartphone and completed the same interaction tasks, including navigating the application menus, scanning a printed property marker, viewing the three-dimensional building model, and accessing property information. Participants completed the questionnaire only after finishing all assigned tasks. Using the same device and procedure reduced variation caused by differences in hardware and evaluation conditions. The application-specific evaluation instrument consisted of ten items measured using a five-point Likert scale. Before the main evaluation, the instrument was examined through a separate pilot test involving 45 respondents who were not included in the main evaluation sample. Item validity was analyzed in SPSS using Pearson Product-Moment item-total correlations. With 45 pilot responses, degrees of freedom of 43, and a two-tailed significance level of 0.05, the critical correlation value was 0.294. An item was considered valid when its calculated correlation coefficient exceeded this value. Internal consistency was subsequently assessed using Cronbach's Alpha. The obtained coefficient of 0.678 indicated moderate internal consistency and was considered adequate for the exploratory, application-specific evaluation, although it was not interpreted as strong reliability. Finally, the Disseminate stage focused on documenting the development and evaluation processes and reporting the findings through scientific publication. Dissemination in this study did not include commercial distribution or real-world implementation of the application. Consequently, the study provides evidence of functional correctness and user acceptance under the specified evaluation conditions rather than evidence of real-world marketing effectiveness

2.2 Application Development

The proposed application was developed as an Android-based marker-based AR system for interactive property promotion. The application extends conventional printed property brochures by overlaying three-dimensional virtual building models onto physical markers, enabling users to explore property information through a smartphone camera. The development process followed the system requirements identified during the Define phase and the application design produced during the Design phase of the 4D model.

The software and hardware environment used during the development process is summarized in table 3.

Table 3. Development Environment

Phase	Activities
Target Platform	Android
Development Engine	Unity
AR SDK	Vuforia SDK
Programming Language	C#
3D Modelling Software	Blender
AR Technique	Marker-Based Augmented Reality

According to table 3, Unity served as the primary development platform for implementing the application logic, user interface, scene management, and interaction mechanisms. Vuforia SDK was integrated to perform marker recognition and real-time object tracking, while Blender was used to create and optimize the three-dimensional property models before deployment into the Unity environment. The overall architecture of the proposed system is illustrated in figure 2.

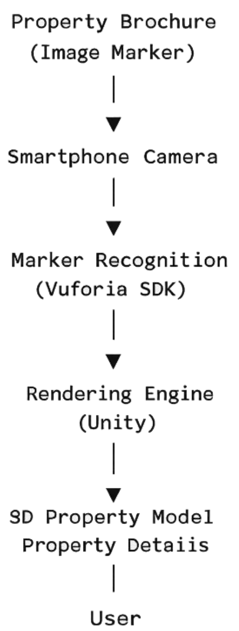

Figure 2. System Architecture

The interaction process begins when the user selects the AR scanning feature and points the smartphone camera toward the printed property brochure. The captured image is processed by Vuforia SDK to identify the registered marker. Once a valid marker is detected, Unity retrieves the associated three-dimensional model and renders it on top of the physical brochure in real time. The rendered object remains synchronized with the marker position, allowing users to inspect the property model from multiple viewing angles through natural camera movement.

The operational workflow of the application is presented in Figure 3.

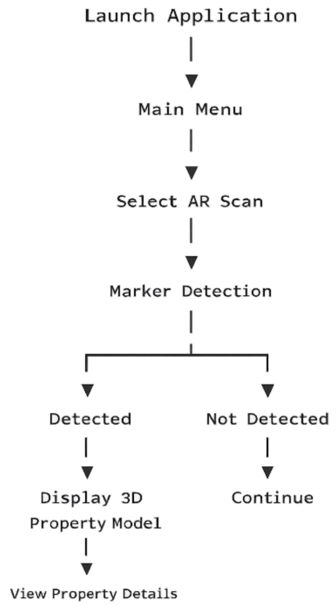

Figure 3. Application Workflow

The application provides several functional modules to support property visualization and user interaction. These modules are summarized in Table 4.

Table 4. Application Features

Feature	Description
Home	Displays the main navigation menu
AR Scan	Activates the camera and performs marker recognition
3D Visualization	Displays the three-dimensional property model
Propoerty Details	Presents detailed property information
Help	Provides instructions for application usage
About	Displays application information
Exit	Closes the application

The user interface was designed with a simple navigation structure to minimize interaction complexity and facilitate first-time use. The AR Scan module serves as the primary feature of the application, while the remaining modules provide supporting information and navigation. The three-dimensional property models were optimized before deployment by adjusting object scale, orientation, texture mapping, and rendering parameters to ensure stable visualization and efficient performance on Android devices.

The resulting application integrates conventional promotional media with mobile AR technology into a unified interactive platform. Through the combination of brochure-based markers, real-time tracking, and three-dimensional visualization, users can obtain a more comprehensive understanding of the property while maintaining the familiarity of existing promotional materials.

2.3 Functional Testing

Functional testing was conducted to verify whether each feature of the developed application operated according to the predefined functional requirements. The black-box testing method was employed because the evaluation focused on observable system responses to user inputs without examining the internal source code or program structure. The testing was performed by the application developer after the implementation stage and before the user evaluation. Seven test cases were prepared to cover the application's main functional modules: application initialization, main-menu navigation, marker recognition and three-dimensional object visualization, property information display, user guidance, developer information, and application termination. Each test case was executed three times, resulting in 21 test executions. Repeated testing was conducted to determine whether the application consistently produced the expected response for each functional scenario. For every execution, the observed system response was compared with the corresponding expected outcome. An execution was classified as Passed when the observed behaviour matched the expected result and failed otherwise. A functional module was considered valid only when its corresponding test case produced the expected result in all three repetitions. All functional tests were conducted using the same Android smartphone, application build, and printed brochure markers to maintain consistency across the test executions. The smartphone met the minimum operating requirements established during application development and was therefore used to examine whether the application could perform its main functions under minimum supported conditions. All seven test cases produced the expected results in each of the three repetitions, indicating that the application operated consistently under these conditions. However, the detailed hardware specifications and Android version of the testing device were not documented. Therefore, the results are limited to the device and testing conditions used in this study and should not be interpreted as evidence of compatibility across all Android devices. The testing was also limited to functional verification and did not assess application performance, security, multi-device compatibility, or effectiveness in real-world property marketing. Future studies should document complete device specifications and conduct compatibility testing on Android devices with different hardware configurations.

2.4 User Evaluation

a. Participants

The evaluation involved 51 participants, consisting of six representatives from the property developer and forty-five prospective users from the general public. Since the number of participants was relatively limited, all eligible respondents were included in the evaluation process.

Before completing the evaluation, each participant independently operated the application using an Android smartphone. The evaluation session included navigating the application menus, scanning the property brochure, visualizing the three-dimensional building model, and accessing the available property information. User responses were collected only after all interaction tasks had been completed.

b. Evaluation Instrument

User perception was measured using a structured evaluation instrument developed specifically for the proposed application. The instrument consisted of ten evaluation items covering both technical performance and user interaction aspects. Unlike standardized usability instruments, the evaluation instrument was designed according to the characteristics of the developed AR application and was subsequently validated and tested for reliability before being used for data collection.

Responses were recorded using a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). For presentation purposes, the evaluation items were grouped into several dimensions, as shown in Table 5.

Table 5. User Evaluation Instrument

Evaluation Dimension	Items	Evaluation Aspect
Interface Design	Q1-Q2	Visual appearance and menu organization
Marker Recognition	Q3-Q4	Marker detection and autofocus performance
AR Visualization	Q5-Q6	Quality and interactivity of the three-dimensional model
Information Quality	Q7	Clarity and completeness of property information
System Performance	Q8	Application stability during operation
Ease of Use	Q9	Simplicity of application operation
Overall Benefit	Q10	Overall usefulness of the application for property promotion

c. Data Collection Procedure

The evaluation was conducted individually under the same testing procedure for all participants. Initially, participants received a brief explanation regarding the objectives of the evaluation and the basic operation of the application. They were then instructed to explore every available feature, including AR scanning, three-dimensional visualization, and property information display.

After completing the interaction session, participants evaluated their experience by completing the evaluation instrument. The collected responses were subsequently used for validity testing, reliability analysis, and descriptive statistical analysis. The overall evaluation procedure is illustrated in Figure 4.

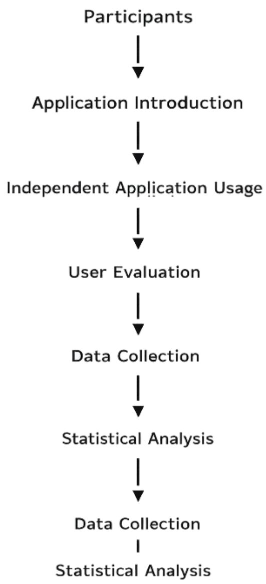

Figure 4. User Evaluation Procedure

d. Instrument Validation

Before conducting the main analysis, the validity of the evaluation instrument was examined using the Pearson Product Moment Correlation method. This procedure was performed to determine the degree of correlation between each evaluation item and the overall instrument score, ensuring that every item appropriately measured the intended evaluation aspect. The validity analysis was conducted prior to interpreting the participants' responses.

e. Reliability Analysis

The internal consistency of the evaluation instrument was assessed using Cronbach's Alpha coefficient. Reliability analysis was carried out after the validity assessment to ensure that the instrument consistently measured users' perceptions of the developed application. The obtained reliability coefficient was subsequently interpreted before performing the descriptive analysis presented in the Results section.

2.5 Data Analysis

The collected data were analyzed using descriptive statistical analysis to summarize users' perceptions of the developed application. For each evaluation item, the mean score was calculated based on the responses obtained from all participants. The mean value represents the overall user perception, where higher scores indicate a more positive evaluation of the corresponding application aspect.

To facilitate interpretation, the calculated mean scores were converted into qualitative categories using predefined intervals derived from the five-point Likert scale. The interpretation categories ranged from Very Poor, Poor, Fair, Good, to Very Good. This categorization enabled the evaluation results to be interpreted consistently across all assessment dimensions.

In addition to descriptive statistics, the evaluation instrument was first examined through validity and reliability analyses to ensure that the collected responses were appropriate for further interpretation. The results of the functional testing, instrument validation, reliability analysis, and user evaluation are presented and discussed in the following section.

III. RESULT AND ANALYSIS

This section presents the implementation and evaluation results of the proposed mobile AR application for residential property promotion. The discussion begins with the implementation of the developed application, followed by the results of functional testing, instrument validation, reliability analysis, and user evaluation. Together, these findings demonstrate the capability of the proposed application to integrate interactive three-dimensional visualization with conventional promotional media while ensuring functional correctness and a positive user experience.

3.1 Implementation AR Application

The proposed mobile AR application was successfully implemented to enhance residential property promotion through interactive three-dimensional visualization. Unlike conventional promotional brochures that rely solely on static images and textual descriptions, the developed application integrates marker-based AR technology to provide prospective customers with an immersive visualization of residential properties using an Android smartphone. The implementation was carried out using Unity as the primary development platform, Vuforia SDK for marker recognition, and Blender for creating three-dimensional residential models. Marker-based tracking was selected because it provides reliable recognition performance while remaining practical for real-world property marketing. Through this approach, conventional printed brochures continue to serve as promotional media while simultaneously functioning as AR markers that activate interactive visualization. The developed application consists of three primary functional modules: the User Interaction Module, the AR Visualization Module, and the Property Information Module. These modules operate together to provide an integrated promotional experience that combines conventional marketing materials with interactive digital content.

a. User Interaction Module

The application begins with a user interface designed to provide straightforward navigation for first-time users. As shown in Figure 5, the main interface serves as the central navigation point, allowing users to access the application's primary functions through a simple menu structure. The available functions include AR visualization, property information, application guidance, developer information, and application settings. The interface adopts a minimalist design approach by reducing unnecessary navigation complexity while maintaining

International Journal of Computer and Information System (IJCIS)
Peer Reviewed – International Journal
Vol : Vol. 07, Issue 03, August 2026
e-ISSN : 2745-9659
https://ijcis.net/index.php/ijcis/index

direct access to essential application functions. This design supports ease of use, particularly for users with limited experience using Augmented Reality applications, and minimizes the learning effort required before interacting with the visualization features.

Figure 5. Main Interface of the Developed Application

b. AR Visualization Module

The AR Visualization Module represents the principal functionality of the proposed application. After the smartphone camera detects a valid brochure marker, the application retrieves and renders the corresponding three-dimensional residential model in real time. The virtual object is accurately overlaid onto the physical brochure, allowing users to observe the property from multiple viewing angles simply by moving the smartphone around the marker.

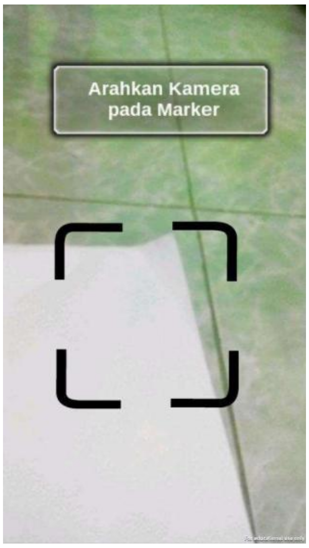

Figure 6. Marker Detection Process

As illustrated in Figure 6 and 7, the integration of marker recognition and real-time rendering enables users to interact naturally with the virtual object while maintaining stable visualization throughout the observation process. Compared with conventional brochure-based promotion, this approach provides a richer understanding of the property's physical appearance and spatial characteristics without requiring prospective customers to visit the actual location. Furthermore, the marker-based visualization approach maintains compatibility with existing promotional workflows since developers can continue distributing printed brochures while simultaneously offering an interactive digital experience through mobile devices.

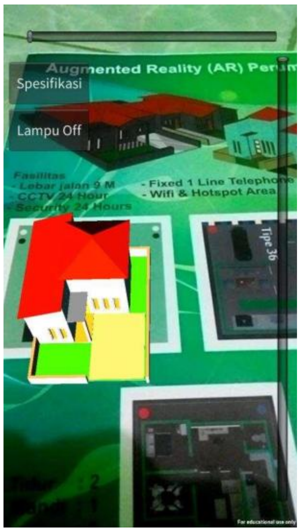

Figure 7. Marker Detection and AR Visualization

c. Property Information Module

In addition to three-dimensional visualization, the application integrates property-related information into the same interaction environment. As presented in Figure 8, users can access detailed housing specifications and descriptive information immediately after interacting with the AR visualization. This integration eliminates the need to obtain information from multiple promotional sources.

Figure 8. Property Information Module

The Property Information Module complements the visualization process by providing textual descriptions that cannot be fully represented through three-dimensional models alone. Combining interactive visualization with supporting information enables prospective customers to develop a more comprehensive understanding of the promoted residential property, thereby improving the effectiveness of the promotional process.

The implementation of these functional modules demonstrates the successful realization of the proposed application design presented in the previous section. By integrating user-friendly navigation, marker-based three-dimensional visualization, and comprehensive property information into a single mobile platform, the developed application extends the functionality of conventional printed promotional media without altering existing marketing practices.

Before evaluating users' perceptions of the application, it was necessary to verify that every implemented feature operated according to its intended functionality. Therefore, functional testing was conducted to assess the correctness of each application module. The results of this testing are presented in the following section.

3.2 Functional Testing

Functional testing was conducted to verify that each implemented feature of the proposed application operated according to its intended functionality. Following the black-box testing procedure described in Section 2.3, each application module was executed under predefined testing scenarios, and the observed outputs were compared with the corresponding expected results. The testing covered all primary functionalities of the application, including application initialization, menu navigation, marker-based AR visualization, property information display, user guidance, developer information, and application termination. The results of the functional testing are presented in Table 7.

Table 7. Results of Functional Testing

Functional Module	Test Scenario	Expected Result	Result
Splash Screen	Launch the application	The splash screen is displayed correctly before entering the main menu.	Pass
Main Menu	Open the application	All menu options are displayed and function properly.	Pass
AR Visualization	Scan a valid brochure marker	The application successfully detects the marker and renders the corresponding 3D residential model	Pass
Property Information	Open the property information menu	Property specifications and descriptions are displayed correctly.	Pass
User Guidance	Open the instruction menu	Application usage instructions are displayed correctly.	Pass
Developer Information	Open the About menu	Developer information is displayed correctly.	Pass
Exit	Close the application	The application terminates successfully without errors.	Pass

The functional testing results show that all evaluated modules successfully produced the expected outputs. No functional errors were identified during the execution of the predefined testing scenarios, indicating that the developed application satisfied all specified functional requirements. For marker-based Augmented Reality applications, functional verification is an essential prerequisite before conducting user evaluation. Errors in marker recognition, object rendering, or navigation may significantly influence users' perceptions of the application and potentially bias the evaluation results. By confirming that every application module functioned correctly prior to the evaluation stage, the subsequent user assessment was able to focus on the quality of the developed application rather than software implementation issues. Overall, the functional testing confirms that the proposed application is functionally stable and suitable for user evaluation.

3.3 User Evaluation

User evaluation was conducted to assess users' perceptions of the developed AR application for residential property visualization. A total of 51 respondents participated in the evaluation, consisting of 45 public users and six property developers. Before completing the questionnaire, respondents were asked to explore the application's primary functionalities, including marker recognition, three-dimensional visualization, property information, and menu navigation.

The questionnaire consisted of ten evaluation statements measured using a five-point Likert scale. Prior to analyzing the evaluation results, the questionnaire was verified through validity and reliability analyses. The evaluation results were then analyzed separately for public users and developers because both groups represented different perspectives regarding the application.

3.3.1 Questionnaire Verification

The questionnaire was first evaluated to ensure that it was suitable for measuring users' perceptions. Item validity was examined using the Pearson Product-Moment correlation based on responses collected from the 45 public users. Each questionnaire item was considered valid when its calculated correlation coefficient exceeded the critical value of 0.294, detail of the result can be seen in table 8.

Table 8. Instrument Validity Results

Item	**Evaluation Aspect**	$r_{calculated}$	$r_{critical}$	**Result**
Q1	Initial application interface	0.346	0.294	Valid
Q2	Menu Clarity	0.660	0.294	Valid
Q3	Marker detection	0.539	0.294	Valid
Q4	Camera Autofocus	0.393	0.294	Valid
Q5	3D Property Visualization	0.670	0.294	Valid
Q6	Application Interactivity	0.601	0.294	Valid
Q7	Information Clarity	0.549	0.294	Valid
Q8	System Performance	0.540	0.294	Valid
Q9	Ease of use	0.322	0.294	Valid
Q10	Usefulness for property promotion	0.478	0.294	Valid

All questionnaire items satisfied the validity criterion, with correlation coefficients ranging from 0.322 to

0.670. These results indicate that each evaluation item adequately represented the intended construct and could therefore be retained for further analysis. The internal consistency of the questionnaire was subsequently evaluated using Cronbach's Alpha.

Table 9. Instrument Reliability Result

Number of Respondents	Number of Items	Cronbach's Alpha	Interpretation
45	10	0.678	Reliable

According to table 9, the obtained Cronbach's Alpha coefficient of 0.678 indicates acceptable internal consistency. Therefore, the questionnaire was considered sufficiently reliable for evaluating users' perceptions of the developed application.

3.3.2 User Perception

The responses collected from public users and developers were analyzed descriptively. Since the two respondent groups evaluated the application from different perspectives, their results are presented separately. Public users primarily assessed the application based on usability and overall user experience, whereas developers focused more on the technical implementation of the AR system. The evaluation results are summarized in table 10.

Table 10. User Evaluation Results

Evaluation Aspect	Public Users (%)	Developers (%)
Initial application interface	88	86.67
Menu Clarity	84.44	86.67
Marker detection	85.33	90
Camera Autofocus	85.33	83.33
3D Property Visualization	86.67	86.67
Application Interactivity	83.56	83.33
Information Clarity	83.56	83.33
System Performance	83.11	86.67
Ease of use	84	83.33
Usefulness for property promotion	87.11	83.33
Overall Evaluation	**85.11**	**85.33**

Based on table 10, it can be seen that in overall, both respondent groups demonstrated a positive perception of the developed application. Public users reported an overall evaluation score of 85.11%, while developers reported 85.33%. The difference between the two groups was only 0.22 percentage points, indicating that the application was consistently accepted from both usability and technical perspectives. The consistently high evaluation scores suggest that integrating Augmented Reality into residential property promotion successfully enhances users' interaction with conventional printed brochures. The results also indicate that both general users and professional developers perceived the application as useful, functional, and sufficiently mature for practical implementation.

The interface-related aspects received consistently high evaluations from both respondent groups. Among public users, the initial application interface obtained the highest score (88.00%), indicating that respondents considered the application's appearance attractive and easy to understand during first-time use. Similarly, the three-dimensional property visualization received identical scores of 86.67% from both public users and developers. This result demonstrates that the three-dimensional models successfully presented residential properties in a clear and realistic manner. Compared with conventional brochures that rely solely on two-dimensional images, the AR visualization provided a richer representation of the property, allowing users to better understand the building layout and overall appearance. The high evaluation of these aspects confirms that visual presentation remains one of the primary strengths of the developed AR application.

Developers assigned the highest evaluation to marker detection, achieving 90.00%, while public users also provided a positive evaluation of 85.33%. These findings indicate that the marker recognition mechanism performed reliably and successfully displayed the corresponding three-dimensional objects during normal operation. Application performance and camera autofocus also received positive evaluations from both respondent groups. Nevertheless, these aspects obtained relatively lower scores than marker detection, suggesting that application responsiveness could still be improved. Differences in smartphone hardware specifications, camera quality, and environmental lighting conditions may influence AR tracking performance and therefore represent potential areas for future optimization. Overall, the technical evaluation demonstrates that the developed application provides stable AR functionality while maintaining satisfactory system performance.

The usability related aspects including menu clarity, application interactivity, ease of use, information clarity, and usefulness all received positive evaluations exceeding 83%. Among these aspects, the usefulness of the application for property promotion achieved one of the highest evaluations from public users (87.11%). This finding indicates that respondents considered the application beneficial for obtaining property information and supporting the property selection process. Although application interactivity and information clarity received slightly lower evaluations than other aspects, their scores remained within the positive category. These findings suggest that respondents experienced little difficulty when interacting with the application and considered the provided information sufficiently understandable. Overall, the usability results demonstrate that the application successfully combines interactive visualization with an intuitive user interface, enabling users to access property information efficiently.

Although all evaluation aspects received positive assessments, several opportunities for further improvement remain. Future development should focus on enhancing application responsiveness across different smartphone specifications, improving autofocus performance under varying lighting conditions, and presenting property information in a more structured and comprehensive manner. In addition, future studies may incorporate larger and more diverse respondent groups to further validate user acceptance across different demographic backgrounds. Evaluating the application in real-world property marketing scenarios would also provide valuable insights into its practical effectiveness and long-term adoption. Overall, the evaluation results confirm that the proposed AR application provides an effective and interactive alternative to conventional residential property promotion. The consistently positive evaluations from both public users and developers demonstrate that the integration of brochure-based markers with three-dimensional visualization offers a practical solution for improving users' understanding and engagement during property exploration.

VI. CONCLUSION

This study developed an Android-based marker-based AR application that integrates printed property brochures with interactive three-dimensional building visualization. Black-box testing confirmed that the main application features operated consistently according to the specified functional requirements under the tested conditions. Evaluations involving public users and property developers also indicated positive user acceptance. These findings support the functional correctness and positive perception of the application, but they do not establish its effectiveness in real-world property marketing. The practical implication of this study is that property developers may supplement existing printed brochures with interactive visualization without replacing a familiar and accessible promotional medium. The application can help present building forms and property information more interactively during initial property exploration. Nevertheless, its use in actual marketing activities requires further field validation before conclusions can be drawn regarding purchasing decisions, customer engagement, or marketing performance. This study is limited by purposive sampling, the relatively small number of property-developer respondents, the absence of respondent demographic data, and evaluation under controlled conditions using a single Android device that met the minimum operating requirements. The study also measured functionality and user perceptions rather than behavioural or marketing outcomes. Future research should test the application on multiple Android devices, involve larger and more diverse participant groups, and evaluate it in real property-marketing settings. Comparative studies between AR-assisted and conventional brochures should also examine measurable outcomes such as task completion, information recall, user engagement, purchase intention, and application performance under different lighting and marker-detection conditions.

THANK-YOU NOTE

This research is fully funded by Penelitian Individu Dosen (PID) Universitas Muhammadiyah Surakarta.

REFERENCES

[1] Ali O, Osmanaj V, Kwiatek P, Chimhundu R, Alryalat M, Dwivedi YK. The impact of technological innovation on marketing: individuals, organizations and environment: a systematic review. Economic research-Ekonomska istraživanja. 2023 Dec 26;36(3). https://doi.org/10.1080/1331677X.2023.2210661.

[2] Subekti TA, Nugroho SS. Impact of information usefulness and adoption in social media on purchase intention: Evidence of Indonesia. Benefit: Jurnal Manajemen dan Bisnis. 2023 Dec 27;8(2):179-96. https://doi.org/10.23917/benefit.v8i2.2461.

[3] Caliskan A, Özkan Özen YD, Ozturkoglu Y. Digital transformation of traditional marketing business model in new industry era. Journal of Enterprise Information Management. 2021 Jul 15;34(4):1252-73. https://doi.org/10.1108/JEIM-02-2020-0084

[4] Juanna A, Monoarfa MA, Podungge R, Tantawi R. Identification of trends in business promotion and marketing using video-based content on social media. Jambura Science of Management. 2024 Jul 1;6(2):88-103. https://doi.org/10.37479/jsm.v6i2.23966

[5] Khanom MT. Using social media marketing in the digital era: A necessity or a choice. International Journal of Research in Business and Social Science (2147-4478). 2023;12(3):88-98. https://doi.org/10.20525/ijrbs.v12i3.2507.

[6] Laghari AA, Jumani AK, Kumar K, Chhajro MA. Systematic Analysis of Virtual Reality & Augmented Reality. International Journal of Information Engineering & Electronic Business. 2021 Feb 1;13(1). https://doi.org/10.5815/ijieeb.2021.01.04.

[7] Mauri M, Rancati G, Riva G, Gaggioli A. Comparing the effects of immersive and non-immersive real estate experience on behavioral intentions. Computers in Human Behavior. 2024 Jan 1;150:107996. https://doi.org/10.1016/j.chb.2023.107996.

[8] Nugroho AA, Dwijayanti I, Prayito M, Noordin MK, Fenyvesi K. Design of algebra digital book on mixed reality-based to improve learner's numeracy literacy. JRAMathEdu (Journal of Research and Advances in Mathematics Education). 2024 Oct 31:176-89. https://doi.org/10.23917/jramathedu.v9i4.4745.

[9] Sudarmilah E, Maelani A. Augmented reality based-learning media of computers. Procedia Environmental Science, Engineering and Management. 2021;8(4):819-35.

[10] Deep S, Vishnoi S, Malhotra R, Mathur S, Yawale H, Kumar A, Singla A. Influence of augmented reality and virtual reality on real estate investment decisions: understand consumer perspective in Indian AEC industry. Engineering, Construction

and Architectural Management. 2025 Feb 4;32(2):1122-40. https://doi.org/10.1108/ECAM-04-2023-0327.

[11] Ibrahim FA, Boying W, Shafiei MW, Razak RA, Ishak N. Augmented reality (AR) as A promotion tool in influencing housing purchase intention. Journal of Advanced Research in Applied Sciences and Engineering Technology. 2023;29(3):251-9. https://doi.org/10.37934/araset.29.3.251259.

[12] Susanti N, Adiyono S, Romadhon Z. Transformasi Digital: Aplikasi Manajemen Pemasaran Berbasis Web untuk PT. Arto Podomoro Mulyo. jikstik [Internet]. 2024 Mar. 12 [cited 2026 Aug. 9];23(1):93-104. https://doi.org/10.32409/jikstik.23.1.3561.

[13] Sekar AN, Nathania AL, Tsalasa KS, Permana F. Transforming real estate sales and marketing with AReal: Sustainable solutions through augmented reality. Procedia Computer Science. 2024 Jan 1;245:365-74. https://doi.org/10.1016/j.procs.2024.10.262.

[14] Setyadi R, Ranggadara I. Augmented reality using features accelerated segment test for property catalogue. TELKOMNIKA (Telecommunication Computing Electronics and Control). 2020 Feb 1;18(1):140-7. https://doi.org/10.12928/telkomnika.v18i1.13039.

[15] Ambre TP, Khalane PP, Kanjiya SD, Kenny J. Implementation of the 3d Digitalized Brochure using Marker-based Augmented Reality for Real Estates. In2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA) 2020 Jul 15 (pp. 483-487). IEEE. https://doi.org/10.1109/ICIRCA48905.2020.9183196

[16] Dutta R, Mantri A, Singh G. Evaluating system usability of mobile augmented reality application for teaching Karnaugh-Maps. Smart Learning Environments. 2022 Jan 15;9(1):6. https://doi.org/10.1186/s40561-022-00189-8.

[17] Thiagarajan S, Semmel DS, Semmel MI. Instructional Development for Training Teachers of Exceptional Children: A Sourcebook. Leadership Training Institute/Special Education, University of Minnesota; 1974

[18] Arvianto F, St Y S. Designing an instrument to measure digital literacy competence using the 4D model. International Journal of Instruction. 2023 Oct 1;16(4):845-60. https://doi.org/10.29333/iji.2023.16447a

[19] Indaryanti RB, Harsono H, Sutama S, Murtiyasa B, Soemardjoko B. 4D research and development model: Trends, challenges, and opportunities review. Jurnal Kajian Ilmiah. 2025 Jan 31;25(1):91-8. https://doi.org/10.31599/na7deq07.

[20] Amalina SL, Pradana MD, Anggraini A. Development of Augmented Reality E-Booklet to Improve Students' Learning Outcomes on Earth Structure Material. AS-SABIQUN. 2025 Jul 1;7(4):914-29. Ramadhani IK, Rosy B. The Development of Augmented Reality (AR) Based Learning Modules in Office Technology and Correspondence Subjects. Jurnal Pendidikan

[21] Ramadhani IK, Rosy B. The development of augmented reality (AR) based learning modules in office technology and correspondence subjects. Jurnal Pendidikan Administrasi Perkantoran (JPAP). 2023 Aug 31;11(2):99-108. https://doi.org/10.26740/jpap.v11n2.p99-108.