Evaluating User Acceptance and Usability of AR-Based Indoor Navigation in a University Setting: An Empirical Study

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***Abstract*—This paper presents the development and usability evaluation of a mobile augmented reality (AR) application designed to support indoor navigation within a higher education setting. The system offers real-time visual and audio guidance without requiring additional infrastructure, leveraging spatial anchors, QR code initialization, and compatibility with both ARCore and ARKit platforms. Users can select destinations such as classrooms, offices, and restrooms, and follow augmented reality overlays to reach them efficiently. A review of existing AR navigation systems highlights current technological approaches and gaps in user-centered research, particularly within academic institutions. Building on these findings, the proposed application was tested in a large-scale empirical study involving 256 students, situated in the context of spatial computing within a university environment. Data collection was based on the System Usability Scale and the Technology Acceptance Model, with four research hypotheses examining ease of use, usefulness, system responsiveness, and continued usage intention. Results revealed significant correlations between intuitive design and usability scores, as well as between perceived usefulness and behavioral intention to reuse the application. These findings reinforce the value of user-centered design in developing infrastructure-free mobile AR systems and demonstrate their potential to improve spatial orientation in complex educational building.**

Keywords*—Augmented reality; indoor navigation; mobile application; usability evaluation; ARCore; higher education; spatial computing

I. Introduction

Indoor navigation continues to pose significant challenges across various public and institutional domains such as healthcare, transportation, and education. Conventional methods—including static signage, printed maps, and directory boards—often prove insufficient in large, unfamiliar, or dynamically changing environments [1]. This is particularly relevant in academic settings, where students and visitors frequently navigate multi-functional and multi-story buildings without prior familiarity.

Augmented Reality (AR) offers promising solutions by superimposing digital content—directional arrows, labels, or information panels—directly onto the user's physical surroundings, thus supporting real-time, intuitive orientation [2]. AR has already demonstrated benefits in outdoor wayfinding, primarily through GPS-based systems [3]. However, GPS signals are typically unavailable indoors, necessitating the use of alternative localization strategies such as Visual Positioning Systems (VPS), Simultaneous Localization and Mapping (SLAM), and visual-inertial odometry [4].

Recent advancements in mobile AR technologies and spatial computing frameworks have enabled the development of indoor navigation systems across various domains, including healthcare, retail, cultural heritage, and education. These systems commonly employ technologies such as WiFi fingerprinting, Bluetooth Low Energy (BLE) beacons, SLAM, or markerless tracking, often in combination with AR platforms like ARKit and ARCore [5]. While promising results have been reported, academic institutions—despite their navigational complexity—remain comparatively underexplored. Moreover, many studies focus on proof-of-concept applications or small-scale usability assessments, highlighting a need for broader empirical validation in dynamic, real-world settings such as university campuses [6].

This paper addresses this gap by presenting the development and evaluation of a mobile AR navigation system designed for indoor use within a university campus building. The application is based on Unity 3D and the ARway SDK and is compatible with ARCore and ARKit, enabling deployment on both Android and iOS platforms without the need for additional infrastructure. The system relies on spatial anchors and camera-based localization initialized via QR code scanning, guiding users through directional AR overlays and audio cues.

The main contribution of this study is twofold: first, it introduces a scalable, infrastructure-free AR application adapted to academic environments; second, it provides a comprehensive empirical evaluation based on a large user study (N = 256), focusing on perceived usability, system responsiveness, and user acceptance. A structured questionnaire derived from the System Usability Scale (SUS) [7] and the Technology Acceptance Model (TAM) [8] was used to test four research hypotheses concerning intuitiveness, perceived usefulness, and behavioral intention to reuse the application.

The findings presented here extend prior work in AR-based indoor navigation and contribute novel insights into mobile AR usability within educational institutions, with implications for the design of future user-centered navigation systems in complex-built environments.

This paper is organized as follows: Section II provides a review of related work in the field of augmented reality-based indoor navigation, with particular focus on systems implemented in educational settings. Section III presents the research methodology, including system development, participant demographics, and the experimental setup. Section IV discusses the empirical results from the usability evaluation and hypothesis testing. Section V outlines the study's key limitations and their implications. Finally, Section VI concludes the paper by summarizing the main findings and suggesting directions for future research.

By situating this work within the broader landscape of spatial computing and user-centered AR design, the study offers novel insights into the deployment of infrastructure-free navigation systems in higher education. Through one of the largest usability evaluations conducted in a real university setting, the findings provide evidence of how intuitive and responsive AR interfaces can improve indoor orientation and support student navigation experiences in complex buildings.

II. Related Work

Augmented Reality (AR) technologies have gained increasing attention as powerful tools for facilitating spatial orientation in both outdoor and indoor environments. By superimposing digital information—such as directional cues, contextual data, or visual guides—onto the physical world, AR enhances users' spatial cognition, supports real-time decision-making, and improves the overall navigation experience. While outdoor AR navigation systems have become more mature due to their integration with GPS and digital cartography, indoor navigation presents a distinct set of challenges that demand specialized solutions. Factors such as the absence of GPS signals, complex architectural layouts, and the need for micro-localization accuracy require alternative approaches that leverage visual markers, wireless signal mapping, and sensor fusion. As buildings become increasingly multi-functional and dynamic, effective indoor navigation—especially in public or semi-public spaces like airports, hospitals, and university campuses—has become not only desirable, but essential.

This literature review focuses specifically on AR navigation systems designed for indoor environments. By examining a range of implementations, empirical evaluations, and technological strategies, the review identifies trends, challenges, and gaps in the field. The ultimate aim is to contextualize and inform the development and testing of a mobile AR application tailored to indoor navigation within a university building—a scenario that combines both technical complexity and high user variability.

While foundational models such as Spatial Cognition Theory [9] and Situated Learning Theory [10] provide historical context, more recent research has emphasized practical and user-centered approaches for mobile AR navigation in educational settings. Bermejo et al. [11], offer a broad overview of AR applications in learning environments, while Zulfiqar et al. [12], identify both the usability benefits and implementation challenges of AR tools. These perspectives align with the increasing emphasis on mobile HCI, accessibility, and real-world deployment in university contexts.

Contemporary implementations often rely on more recent human-centered design principles and empirical HCI models [13]. Recent studies demonstrate diverse combinations of technologies and contexts: BLE beacons, SLAM, visual-inertial odometry, tactile and audio feedback, and ARCore/ARKit platforms. Use cases range from libraries and office buildings to hospitals, museums, and airports. Notably, several studies focus on accessibility and inclusive design, such as those by Mishra et al. [15] and Jain & Singh [16], while others explore high-accuracy solutions for complex layouts in university and medical facilities [17], [18].

Recent empirical studies have continued to explore the impact of AR on spatial understanding and usability in complex indoor environments. Cheng and Tsai [19] conducted a meta-analysis on the effectiveness of AR in supporting orientation and task efficiency, confirming its benefits in unfamiliar environments like educational campuses. Similarly, Bacca et al. [20] reviewed AR applications in higher education, underscoring the importance of multimodal feedback and responsive interaction design in user navigation experiences.

To summarize these findings, TABLE I. presents a comparative overview of recent and relevant AR systems developed specifically for indoor navigation. The table highlights each system's technological stack, target environment, study design, key findings, and limitations. This focused comparison offers a consolidated view of the current landscape and provides a reference point for the development of the proposed application.

A closer examination of Table I, reveals several trends and research directions. First, BLE beacons, SLAM, and markerless AR remain among the most frequently implemented technologies, often combined with ARCore or ARKit for rendering and interface management. Use cases involving hospitals, libraries, and museums prioritize accessibility and user comfort, while high-precision systems for transportation hubs and campuses aim at efficiency and scalability. University-focused systems are increasing in number, but still underrepresented, creating an opportunity for further research in this domain. Although many applications show high satisfaction and orientation success rates, challenges such as occlusion, signal reliability, infrastructure requirements, and energy consumption persist.

Building upon this landscape, the present research introduces and evaluates a mobile AR application designed to support indoor navigation within a university campus building. The system integrates inertial sensors and spatial anchors to generate real-time directional overlays, assisting users in locating academic spaces such as classrooms, administrative offices, restrooms, and exits. The design emphasizes usability, speed of response, and intuitive interaction, with the goal of supporting both first-time visitors and regular users of the building.

TABLE I. COMPARATIVE ANALYSIS OF RECENT INDOOR AR NAVIGATION SYSTEMS

Study	Environment	Technologies Used	Participants	Key Results	Limitations
Rossi et al. [14]	Office building	Visual markers, ARKit	30	35% reduction in wayfinding time	Requires precise marker placement
Nguyen & Park [5]	Shopping mall	Bluetooth beacons, AR overlays	25	82% accuracy in navigation	Signal interference in crowded areas
Gupta et al. [4]	Hospital	WiFi fingerprinting, SLAM	35	78% room-finding success rate	High computational demands
Mishra et al. [15]	Simulated indoor	Sonar sensors, audio AR	20	90% obstacle avoidance for visually impaired	Latency in real-time audio processing
Jain & Singh [16]	Public library	Tactile feedback, AR overlays	15	85% satisfaction for mobility-impaired users	Battery drain during prolonged use
Chen et al. [17]	University campus	ARCore, visual-inertial odometry	50	81% ease-of-use rating, strong multi-floor support	Learning curve for first-time users
Ahn et al. [18]	Medical facility	LIDAR, SLAM, semantic mapping	40	86% orientation success, cognitive load reduced	LIDAR dependency, limited mobile support
Sato et al. [21]	Museum	Markerless AR, cloud anchors	32	77% task completion, high engagement	Occlusion issues in high-traffic zones
Yamamoto et al. [6]	University building	BLE beacons, 3D AR navigation	50	72% satisfaction, effective in complex layouts	Limited beacon range across floors
Zhao et al. [22]	Conference center	UWB + AR headset	28	88% task success rate, sub-meter precision	High setup cost, headset fatigue
Lee et al. [23]	Airport terminal	5G positioning + AR glasses	45	84% accuracy in terminal routing	Infrastructure dependence on 5G
Fernandez et al. [24]	Large campus	ARCloud + indoor GPS emulation	60	89% efficiency in route following	Data synchronization delays
Watanabe et al. [25]	University library	Computer vision + semantic room tagging	33	80% accuracy in identifying room categories	Tag recognition fails in dim lighting

III. METHODOLOGY

A. Research Design and Context

This study follows an applied, exploratory and user-centered design methodology, combining software development with empirical evaluation. The methodological approach integrates a twofold focus: 1) the design and implementation of a functional AR indoor navigation application, and 2) its validation through structured user testing and statistical analysis.

To structure the evaluation process, two established theoretical frameworks were adopted: the System Usability Scale (SUS) and the Technology Acceptance Model (TAM). These models informed the development of the user questionnaire and the formulation of four research hypotheses, which investigate the relationships between ease of use, system responsiveness, perceived usefulness, and behavioral intention to continue using the application.

The empirical investigation was conducted in a real-world setting—a university campus building—where 256 students participated in testing the application under authentic usage conditions. Their responses were collected immediately after the navigation task was completed.

B. Description of the AR Navigation Application

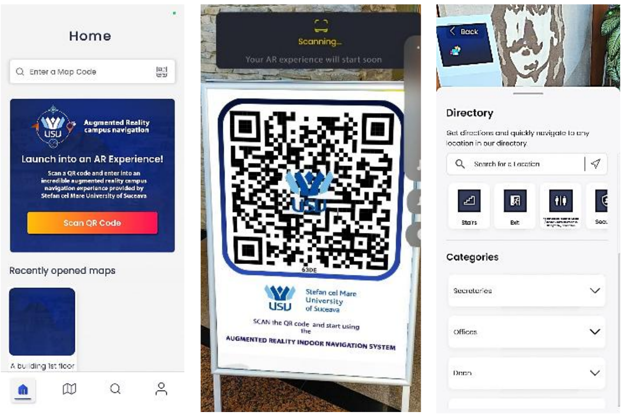
To address the need for effective indoor navigation in academic environments, a mobile augmented reality (AR) application was developed and deployed in one of the university buildings selected as the testing site. The building was instrumented with multiple QR codes positioned both at entry points and at intermediate locations throughout the interior. These QR anchors served not only as access points to initialize spatial localization, but also as recharge points to correct accumulated drift during extended navigation. This design consideration was particularly important given the spatial complexity and scale of a typical campus building, ensuring reliable positioning across the entire route. The application was specifically designed to assist students, staff, and visitors in locating rooms and key functional areas (e.g., classrooms, offices, restrooms) in a fast and intuitive manner, using augmented visual cues superimposed on the physical environment.

1) Technical foundation and compatibility: The system was implemented using Unity 3D as the development platform and ARway SDK, a spatial computing solution that supports real-time mapping and localization without the need for additional physical infrastructure such as Bluetooth beacons or RFID tags. The application leverages Simultaneous Localization and Mapping (SLAM) and Visual Positioning System (VPS) technologies to ensure robust tracking and localization accuracy.

For compatibility, the application supports both Android and iOS devices via ARCore and ARKit, respectively. The solution was optimized to run on standard consumer smartphones, minimizing hardware requirements and maximizing accessibility for users.

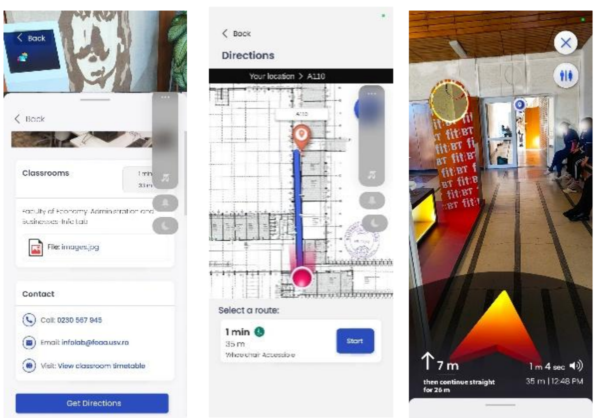
2) Interaction workflow: Navigation begins by opening the application (Fig. 1(a)) and scanning a QR code positioned at the entrance of the building (Fig. 1(b)). This initializes the positioning using spatial anchors and loads the AR environment, placing the user within the building's spatial model. From the location directory (Fig. 1(c)), the user can select a destination from a categorized list including:

- Teaching spaces (lecture halls, classrooms),
- Administrative services (secretariats, offices),
- Facilities (restrooms, common areas),
- Informational points (exhibition rooms, noticeboards).



(a) Main interface. (b) QR Code scanning. (c) Destinations.

Fig. 1. User interface and interaction.



(a) Location details. (b) Location path. (c) Overlaying directions.

Fig. 2. User interface and interaction.

Upon selection and pressing "*Get Directions*" (Fig. 2(a)), the system generates a custom navigation path from the user's current position to the target location (Fig. 2(b)). The path is rendered as a series of directional arrows overlaid on the real environment, updated dynamically as the user advances (Fig. 2(c)). Supplementary features include:

- Audio instructions, synchronized with the visual arrows, offering step-by-step guidance.
- Estimated time and distance, displayed in real time on screen.
- Informational panels, which provide context-sensitive data about destinations (e.g. office hours, room capacity).

The application interface was developed with a strong emphasis on usability and clarity. Buttons are large and spaced appropriately, icons are intuitive, and visual contrast ensures legibility in different lighting conditions.

3) Design considerations and rationale: A key goal in the application design was to reduce cognitive load and promote spatial awareness through AR-enhanced cues. By eliminating reliance on static maps and textual instructions, the application offers a direct and context-sensitive wayfinding experience. In addition, by not requiring external hardware or server-side connectivity for navigation, the system provides a scalable and self-contained solution—particularly important for dynamic environments like university campuses, where, infrastructure may vary and user populations shift frequently.

C. Participant Profile and Study Duration

The empirical evaluation of the AR navigation application involved 256 student participants from Stefan cel Mare University of Suceava, Romania. The vast majority were enrolled in the first (70.7%) and second year (26.2%) of undergraduate study, representing typical users who are less familiar with campus infrastructure and more likely to benefit from orientation support. The remaining participants (3.1%) were from other academic levels, including later undergraduate years and Master's programs.

The study was conducted over a period of two weeks in May 2024, during which students were invited to participate in on-site navigation tests. Out of the total participants, 153 reported having previously used augmented reality applications, while the remaining 103 had no prior experience with AR technologies. This contrast provided a useful dimension in evaluating both usability and adoption potential across different user backgrounds.

D. Experimental Setup and Testing Procedure

To ensure consistency and control across all testing sessions, each participant was required to follow the same predefined navigation route within the selected university building. The target location was intentionally chosen from among less frequently accessed rooms, in order to minimize the likelihood that participants—particularly first-year students—were already familiar with the space. This design choice allowed for a more accurate and unbiased assessment of the application's effectiveness in supporting indoor wayfinding.

Participants began the navigation and followed the application's visual and audio cues to reach the assigned destination. The uniformity of the route across all sessions ensured consistent conditions for evaluating task performance and usability perceptions. After completing the task, participants filled out a structured questionnaire in Google Forms that included items from both the System Usability Scale (SUS) and the Technology Acceptance Model (TAM), targeting key dimensions such as intuitiveness, usefulness, system responsiveness, and behavioral intention to reuse the application.

The complete testing session lasted approximately 10 minutes, including both the navigation interaction and the post task survey. No assistance was offered during the task execution, in order to simulate independent and realistic usage of the application.

E. Research Hypotheses

The hypotheses formulated for this study are as follows:

- Hypothesis 1: Intuitiveness and Usability Correlation.
- Hypothesis 2: Difficulty with Traditional Orientation and Perceived Usefulness.
- Hypothesis 3: Interface Responsiveness and Usability Perception.
- Hypothesis 4: Perceived Usefulness and Continued Use Intention.

The study was approved by the institutional ethics committee of Ștefan cel Mare University of Suceava. All participants were informed about the purpose of the research and their rights prior to participation. Informed consent was obtained from all individuals, and data collection procedures adhered to institutional guidelines on privacy and ethical research conduct. No personally identifiable information was collected or stored during the study.

In order to validate these hypotheses and assess the system's effectiveness, the results of the empirical testing are analyzed and interpreted in the next section.

IV. Results

A. *Hypothesis 1 (H1): There is a Statistically Significant Positive Correlation Between the Users' Perception of the Application's Intuitiveness and their Scores on the System Usability Scale (SUS)*

This hypothesis explored the relationship between how intuitive users found the application and their overall usability ratings, based on the SUS framework. Intuitiveness is a central construct in both user-centered design and the Technology Acceptance Model (TAM), which posit that ease of use directly influences technology adoption.

To test this, a correlation analysis was conducted between two items: "I found the application easy to use" (measuring intuitiveness), and the final SUS score (scaled to 100). Descriptive statistics are presented in Table II, showing a high mean SUS score (M = 96.86, SD = 14.27) and a favorable ease-of-use perception (M = 3.99, SD = 0.95).

TABLE II. Descriptive Statistics for SUS Score and Perceived Ease of Use

Variable	Mean	Std. Deviation	N
SUS Score (Final)	96.86	14.27	256
I found the application easy to use	3.99	0.95	256

A statistically significant, moderate-to-strong positive correlation was found between the two variables (Pearson's r = 0.633, Spearman's ρ = 0.635; p < 0.001), as shown in Table III.

TABLE III. Correlation Between SUS Score and Perceived Ease of Use (N = 256)

Variable Pair	Pearson r	Spearman ρ	Sig. (2-tailed)
SUS Score × Ease of Use Perception	0.633	0.635	< 0.001

Note: Both correlations are significant at the 0.01 level (2-tailed).

These results support the hypothesis, reinforcing that perceived intuitiveness plays a critical role in shaping usability judgments. As shown in Fig. 3, higher ease-of-use ratings consistently aligned with elevated SUS scores, emphasizing the importance of interface design in enhancing user experience.

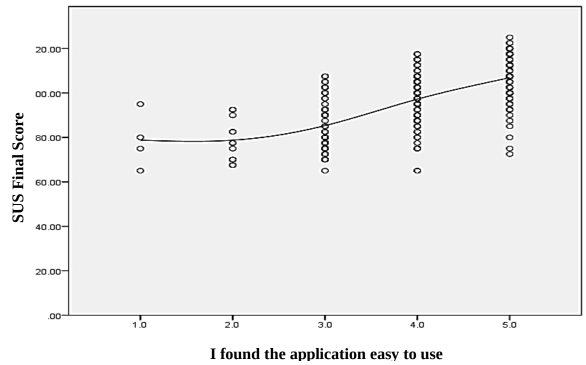


Fig. 3. Analysis of the relationship between users' perceptions of the application's usability and their familiarity with indoor environments.

B. *Hypothesis 2: Indoor Navigation Applications are Perceived as much more Useful by users who Face Difficulties in Traditional Orientation*

This hypothesis explored whether participants with lower familiarity navigating campus buildings would find the AR application more useful. The Technology Acceptance Model (TAM) suggests that perceived usefulness is a critical factor influencing technology adoption, particularly in an unfamiliar or complex environments.

To evaluate this relationship, a correlation analysis was conducted using two self-reported Likert-scale items:

- "How well do you know the buildings/rooms on campus (inside)?" (measuring spatial familiarity)
- "I believe that this application significantly improves my ability to navigate inside campus buildings." (perceived usefulness).

Descriptive statistics for both items are presented in Table IV, indicating moderate familiarity with campus buildings and a generally high perception of the application's utility.

TABLE IV. Descriptive Statistics for Navigation Familiarity and Perceived Usefulness

Variable	Mean	Std. Deviation	N
Familiarity with campus buildings	3.195	0.9037	256
Perceived improvement in indoor navigation	4.059	0.8168	256

Pearson and Spearman correlation analyses revealed a strong and statistically significant inverse relationship (r = –0.866, ρ = –0.886; p < 0.001), as shown in Table V. This suggests that users who were less familiar with the campus environment rated the application as significantly more useful.

As visualized in Fig. 4, users with lower spatial familiarity consistently reported higher perceived usefulness of the AR application. These findings confirm the hypothesis and highlight the potential value of indoor navigation technologies for novice users or those navigating complex built environments such as university campuses.

TABLE V. CORRELATION BETWEEN FAMILIARITY WITH CAMPUS BUILDINGS AND PERCEIVED USEFULNESS (N = 256)

Variable Pair	Pearson r	Spearman ρ	Sig. (2-tailed)
Familiarity × Perceived Usefulness	0.866	0.886	< 0.001

Note: Both correlations are significant at the 0.01 level (2-tailed).

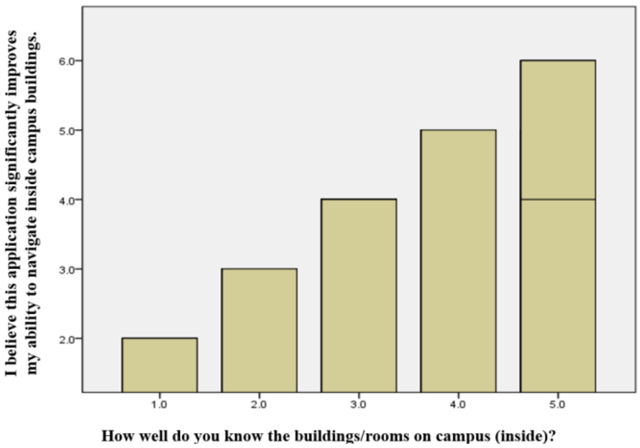


Fig. 4. Cluster analysis of familiarity with campus buildings and perceived utility of indoor navigation app.

This trend suggests an inversely proportional relationship between prior familiarity with the physical environment and perception of the application's utility. Thus, the results support the hypothesis that indoor navigation applications are perceived as more useful by users who experience difficulties in traditional orientation. These results confirm the hypothesis and support the idea that indoor orientation applications can provide real added value, especially in the context of novice users or in complex environments where traditional orientation is difficult.

C. *Hypothesis 3: An Intuitive Interface and a Quick Response Time of the Application Improve the Perception of its Usability*

This hypothesis investigated whether interface intuitiveness and AR content responsiveness influence perceived usability, as measured by the System Usability Scale (SUS). According to user experience principles and the Technology Acceptance Model (TAM), both cognitive simplicity and system performance are key drivers of user satisfaction.

Participants rated two statements on a five-point Likert scale:

- “How intuitive did you find the indoor navigation mode?”
- “How quickly was the AR content (VPS, SLAM) loaded and displayed indoors?”

A multiple linear regression was conducted to determine how these two predictors affected the SUS score. The regression model was statistically significant, $F(2, 253) = 40.22$, $p < 0.001$, accounting for approximately 24.1% of the variance in perceived usability ($R^2 = 0.241$), as shown in Table VI.

TABLE VI. MODEL SUMMARY FOR PREDICTING SUS SCORE

Model	R	R²	Adjusted R²	Std. Error of the Estimate
1	0.491	0.241	0.235	12.874

Both predictors contributed significantly to the model (see Table VII and Table VIII). Response speed of AR content had a stronger effect ($\beta = 0.333$, $p < 0.001$) compared to intuitiveness ($\beta = 0.230$, $p < 0.001$), suggesting that performance responsiveness plays a slightly greater role in shaping usability judgments.

TABLE VII. ANOVA RESULTS FOR SUS REGRESSION MODEL

Source	Sum of Squares	df	Mean Square	F (Sig.)
Regression	13333.365	2	6666.683	40.221 (p < 0.001)
Residual	41934.994	253	165.751	
Total	55268.359	255		

TABLE VIII. REGRESSION COEFFICIENTS FOR PREDICTORS OF SUS SCORE

Predictor	Unstandardized B	Std. Error	Standardized Beta	Sig.
Constant	62.662	4.075	-	< 0.001
Loading speed (AR content)	5.887	1.120	0.333	< 0.001
Intuitiveness	3.492	0.961	0.230	< 0.001

As illustrated in Fig. 5, higher SUS scores were associated with more favorable ratings of both interface intuitiveness and AR responsiveness. These results support the hypothesis and underscore the importance of optimizing both design clarity and performance speed in mobile AR navigation systems.

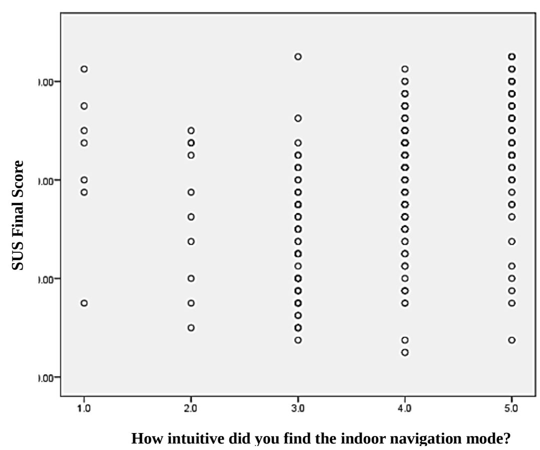


Fig. 5. Relationship between intuitiveness of indoor navigation module and System Usability Scale (SUS) Scores.

D. *Hypothesis 4: The Perception of the Application's Utility Influences the Intention to use it Regularly*

This hypothesis evaluated whether users who perceived the application as useful also expressed a stronger intention to continue using it in the future. In line with the Technology

Acceptance Model (TAM), perceived usefulness is a central determinant of behavioral intention and long-term adoption.

Participants responded to two Likert-scale statements:

- "I believe that this application significantly improves my ability to navigate inside campus buildings." (perceived usefulness).
- "I would be willing to use this application regularly for indoor navigation on campus." (intention to reuse).

Descriptive statistics for both variables are presented in Table IX, showing consistently high ratings for both perceived usefulness (M = 4.059) and reuse intention (M = 4.027).

TABLE IX. DESCRIPTIVE STATISTICS FOR PERCEIVED USEFULNESS AND BEHAVIORAL INTENTION

Variable	Mean	Std. Deviation	N
Perceived Usefulness	4.059	0.8168	256
Intention to Reuse	4.027	0.8698	256

A strong and statistically significant positive correlation was found between the two items (Pearson's $r = 0.761$, Spearman's $\rho = 0.780$; $p < 0.001$), as shown in Table X.

TABLE X. CORRELATION BETWEEN PERCEIVED USEFULNESS AND INTENTION TO REUSE (N = 256)

Variable Pair	Pearson r	Spearman ρ	Sig. (2-tailed)
Usefulness × Intention to Reuse	0.761	0.780	< 0.001

Note: Both correlations are significant at the 0.01 level (2-tailed).

These findings confirm the hypothesis and align with TAM's core assertion that usefulness directly predicts usage behavior. As visualized in Fig. 6, participants who strongly agreed with the application's utility also expressed a higher willingness to use it regularly. This suggests that future AR navigation systems should prioritize tangible user value—such as improved spatial orientation and task efficiency—to support sustained adoption.

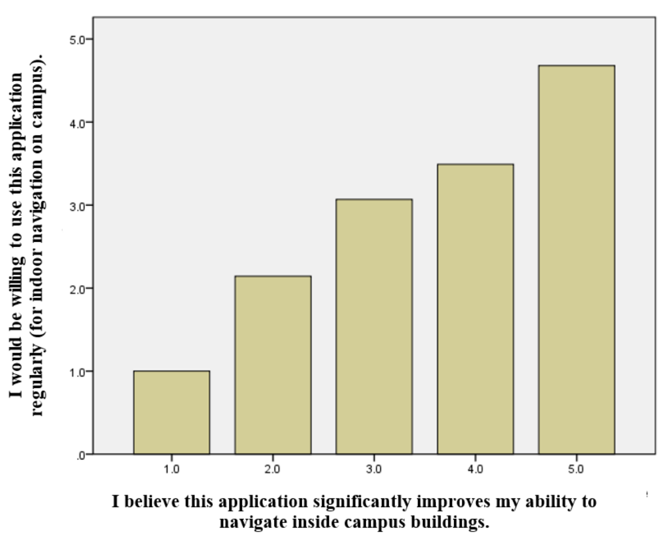


Fig. 6. Conceptual relationship between perceived usefulness and behavioral intention to reuse, based on TAM.

V. LIMITATIONS

While the study provides valuable insights into the usability and user acceptance of an AR-based indoor navigation system in a university setting, several limitations should be acknowledged. First, the navigation system was tested within a single academic building, which may limit the generalizability of the results to other campus environments with different layouts or levels of complexity. Second, the participant sample consisted primarily of first and second-year undergraduate students, a group that may be more receptive to mobile technologies and less representative of the broader university population, including faculty, staff, or postgraduate students.

Third, the evaluation was based on short-term use, focusing on first-time interactions with the application. Long-term usage patterns, user fatigue, and sustained engagement were not explored and remain areas for future research. Finally, environmental factors such as lighting conditions, device performance variability, and accessibility needs were not systematically tested, although they may significantly impact AR experience quality in real-world use.

Addressing these limitations in future studies—through multi-building deployment, broader demographic sampling, and longitudinal testing—could enhance the robustness and applicability of the findings.

VI. CONCLUSION

This study presented the development and evaluation of a mobile augmented reality (AR) navigation system designed for indoor use in an academic environment. Built using Unity and the ARway SDK, the application enables infrastructure-free indoor guidance through visual and auditory cues, anchored via QR codes and spatial localization.

- A large-scale empirical evaluation involving 256 participants demonstrated the application's effectiveness and strong user acceptance. The results offer robust support for all four research hypotheses.
- Users who perceived the application as intuitive and responsive reported significantly higher SUS scores.
- Those with limited prior knowledge of campus interiors rated the system as more useful.
- A strong correlation was found between perceived usefulness and the intention to reuse the application.

These findings, supported by statistically significant correlations and regression models confirm the importance of interface intuitiveness, performance responsiveness, and contextual relevance in shaping AR usability and adoption.

By focusing on a real-world academic scenario and validating the system across a substantial and demographically relevant sample, the study contributes both methodologically and practically. It offers empirical grounding for future AR systems targeting orientation in unfamiliar environments, particularly for students and first-time visitors.

In summary, the study demonstrates that scalable AR indoor navigation systems can meaningfully improve spatial orientation, particularly for novice users. Future directions include expanding to hybrid indoor–outdoor scenarios, integrating dynamic real-time data, and supporting inclusive design through multimodal interaction modalities such as voice guidance and haptic feedback.

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