

Article

Travelers' Continuance Intention to Use Mobile Augmented Reality App in UNESCO World Heritage Sites: An Integrated Model of ECM and UTAUT

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Abstract

Cultural heritage tourism is a vital part of Malaysia's tourism sector, attracting visitors to iconic UNESCO sites like George Town and Melaka. However, these heritage sites face growing challenges from overcrowding and environmental degradation, which accelerate the deterioration of historic architecture and cultural artifacts. Preservation efforts often require site closures, which negatively impact tourist experiences and satisfaction. Thus, augmented reality (AR) offers a solution by supporting heritage management and preservation, allowing visitors to engage with virtual representations via mobile AR apps, thereby enhancing visitor engagement and travel experience. Despite global adoption, mobile AR apps often suffer from low user retention, with many users abandoning them shortly after downloading them. Understanding what drives continued usage is crucial for successful AR implementation. This study integrates the expectation confirmation model (ECM) and the unified theory of acceptance and use of technology 2 (UTAUT2) to examine the determinants affecting user's experiential satisfaction and continued usage intention of mobile AR apps. An online survey of 450 domestic tourists in George Town and Melaka was conducted. Data analysis using structural equation modeling with SmartPLS 4.0 revealed that the integrated model offers a stronger predictive power and significantly outperforms ECM and UTAUT2 individually. The findings contribute valuable insights for researchers, app developers, tourism stakeholders, and policymakers.

Keywords: augmented reality; mobile app; expectation confirmation model; unified theory of acceptance and use of technology 2; experiential satisfaction; continuance intention to use; cultural heritage tourism



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1. Introduction

Tourism is a major economic driver and represents one of the most significant contributors to gross domestic product and employment opportunities in many countries (Pinhal et al., 2025; To & Yu, 2025; Thommandru et al., 2023), including Malaysia. The United Nations World Tourism Organization reported that Malaysia ranked 15th worldwide in 2023 for both international tourist arrivals (20.14 million) and tourism revenue (USD 14.8 billion), demonstrating its sustained prominence in the global tourism sector. Malaysia's popularity among tourists is largely attributed to its rich cultural heritage and diversity. Cultural heritage tourism, as one of the most enduring forms of tourism, remains a primary motivation for people to travel (Kay Smith et al., 2022). The UNESCO World Heritage Sites

in Malaysia, such as George Town and Melaka, further enhance tourists' interest in visiting the country (Carreira et al., 2022). However, when popular World Heritage Sites become overcrowded and exceed their capacity to manage visitors sustainably, negative impacts may occur (Godovykh et al., 2022). These include environmental pollution, accelerated deterioration of infrastructure, and traffic congestion, causing a decline in tourists' experience and residents' quality of life (Hosseini et al., 2021). A similar situation is unfolding in Malaysia, as warned by the UNESCO World Heritage Centre. Following their inscription as UNESCO World Heritage Sites, George Town and Melaka have experienced exponential growth in tourist arrivals which exceeds the sites' carrying capacities, leading to gentrification and over-commercialization (Salim & Rahman, 2022). Overcrowded destinations often face long-term decline as poorly managed sites negatively impact visitor experience and satisfaction (P. Lee et al., 2020; Papadopoulou et al., 2023), unless the issue can be mitigated through smart management, such as smart technology applications to elevate the uniqueness and vibrancy of cultural heritage destinations (Zubiaga et al., 2019).

Led by Arctur, a Slovenian high-tech company specializing in cloud computing and data analytics, Tourism 4.0 (tourism4-0.org) is a concept inspired by Industry 4.0 that aims to digitally transform the tourism sector by building an ecosystem in which stakeholders collaborate to co-create smart, personalized, and sustainable tourist experiences using advanced technologies, including augmented reality (AR) (Korže, 2019). Initially explored by Ronald Azuma, AR uses headgear, handheld devices, or projection systems to allow users to visualize objects generated by computers over actual surroundings in real time (Azuma, 1997). Nowadays, cultural heritage sites around the world are increasingly using AR to enhance visitor interaction and educational experiences (Chauhan & Karthikeyan, 2025). The technology has proved to be useful for the management and preservation of cultural heritage properties (Boboc et al., 2022). With the development of AR tourism experience, they are increasingly seeking more authentic AR experiences (Zhu et al., 2023), particularly among the young travelers who represent one of the largest segments of the global tourism market. Compared to older tourists, they are savvier in technological innovations, relying heavily on digital tools for trip planning, booking, and sharing their experiences on social media, influencing others and co-shaping destination popularity (Pricope Vancia et al., 2023). Although the market outlook for AR is promising, mobile AR apps face concerning "download-discontinue" gap due to technical constraints and poor user experience (Wang et al., 2024). Thus, retaining users is challenging for AR developers (Li et al., 2020).

Despite the growing use of mobile AR apps in cultural heritage tourism, a persistent issue remains where users often discontinue using mobile AR app after a single visit (Marto & Gonçalves, 2019). This poses a challenge not only for AR developers but also for cultural heritage managers seeking to justify continued investment in digital tools (Xu et al., 2022). While AR has the potential to enhance site interpretation and reduce physical crowding through virtual extensions, its long-term value depends on sustained user engagement. However, existing literature has predominantly focused on tourists' initial acceptance and short-term satisfaction (e.g., Li et al., 2020; Boboc et al., 2022), with limited attention to the factors influencing their continuance intention to use mobile AR apps. This creates a gap in understanding how mobile AR can support ongoing visitor interaction, virtual heritage experiences, and destination stewardship beyond the physical visit. Addressing this gap is critical for UNESCO World Heritage Sites, where overcrowding and commercialization threaten the sustainability of tourism.

This study aims to examine the key factors influencing domestic travelers' experiential satisfaction and continuance intention to use mobile AR apps in UNESCO World Heritage Sites. Specifically, it integrates the expectation confirmation model (ECM) and the unified

theory of acceptance and use of technology (UTAUT) to investigate these factors among visitors to George Town and Melaka, Malaysia. The study addresses the following research questions: (1) What factors influence travelers' experiential satisfaction with mobile AR apps? (2) What determines their intention to continue using the mobile AR app? The research focuses on data collected over six months through a self-administered online survey involving 450 domestic tourists. Structural equation modeling (SEM) was employed to analyze the data. This paper is organized into six sections: Section 1 introduces the topic; Section 2 reviews the literature and presents the theoretical framework; Section 3 describes the methodology; Section 4 presents the results; Section 5 discusses implications and limitations; and Section 6 concludes the study.

2. Literature Review

2.1. *Augmented Reality Applications in Cultural Heritage Tourism*

The application of AR technology in mobile environments dates back to the mid-1990s. Nowadays, the public can develop mobile AR apps using a variety of freely available platforms (Syed et al., 2022), such as Unity AR Foundation, ARKit (Apple), ARCore (Google), Vuforia, and many others. Since the launch of Pokémon Go in 2016, consumer awareness, interest, and adoption of mobile AR apps have grown rapidly and at an accelerating rate (Laor et al., 2022). The phenomenon is fueled by recent technological advancements in mobile computing and widespread adoption of smartphones (Yavuz et al., 2021). When users point their smartphones toward an object of interest, the built-in digital camera captures the real-world environment and seamlessly overlays it with 3D graphics, information, or videos in real time, making smartphones the most suitable devices for mobile AR apps. In tourism, smartphones are essential tools in communication, accessing real-time information, navigating unfamiliar environments, and interacting with other digital services. Hence, AR can be seamlessly embedded within existing mobile travel apps to enhance tourist experience by providing interactive, real-time digital content streamed directly through their smartphones. Lonely Planet, a leading travel media company which is well known for its travel guides and expert advice for travelers worldwide, has identified AR as one of the major trends driving transformation for the travel and tourism sector. Not only revolutionizing how travelers engage with destinations, AR also plays a pivotal role in driving growth and innovation within the sector.

The use of mobile AR apps at cultural heritage sites is growing. The capability of mobile AR apps to provide real-time tour information makes them an ideal tool for guiding inexperienced travelers to navigate and explore the surroundings of a destination (Spadoni et al., 2022). Because of overtourism and natural degradation of cultural heritage sites, access to certain areas of the sites is prohibited in order to preserve their original condition (S. Zhang et al., 2023). While these conservation measures are essential, they undoubtedly limit visitors' ability to fully experience and engage with the sites (S. Zhang et al., 2023). AR has the potential to address this constraint through virtual reconstruction of tangible cultural heritage, including historic buildings and cultural artifacts, into 3D objects that can be digitally stored (Boboc et al., 2022). Such an innovative approach not only aids in the restoration and preservation of fragile cultural heritage sites but also provides tourists with equal accessibility to interact with virtual replicas, enabling them to relive and connect with historical events through immersive experiences. In addition, using physical signage to display information is a major drawback in landscape design of cultural heritage sites because this conventional approach may cause disruption or change the destination's original appearance (tom Dieck & Jung, 2018). Ideally, AR can provide an effective solution by overlaying real-time digital signage when users explore the destinations through mobile AR apps (tom Dieck & Jung, 2018). As more AR apps continue to emerge and more tourism-

related enterprises start to leverage the technology to offer value-added products and services, travel is becoming increasingly interactive and enjoyable (Cranmer et al., 2021), the potential of AR technology to enhance travel experience is now widely acknowledged by researchers, as it creates a fun, interactive, and meaningful learning environment for tourists by stimulating their imagination and increasing their interest in cultural heritage sites (Fan et al., 2022; Trunfio et al., 2022). Remarkably, AR apps also give cultural heritage sites an additional layer of competitive advantage in building a distinctive destination branding which can attract more tourists (Graziano & Privitera, 2020).

In Malaysia, the use of mobile AR apps in cultural heritage tourism is becoming widespread through initiatives aimed at enhancing visitor engagement and supporting preservation efforts. For example, a gamified AR app launched at Kellie's Castle in Perak combines 3D overlays, interactive storytelling, and task-based activities to connect younger audiences with cultural narratives, showing improved emotional engagement in usability studies. Similar projects like "Exp AR Malacca" which overlays AR content onto physical maps of traditional Malay houses, and personalized AR walking tours in Melaka's heritage zone, have reported high user satisfaction and stronger cultural appreciation. Experimental tools such as 3D geovisualizations in Sarawak and wearable AR for UNESCO sites further highlight Malaysia's growing interest in technology-driven preservation. Globally, top-rated AR apps like Streetmuseum in the UK and TimeLooper which is deployed at Ancient Rome sites use features such as geo-based storytelling, immersive 3D reconstructions, and gamification to enhance learning and engagement.

Although AR technology is now well-established, recent advancements in its use are greatly enhancing its capabilities within cultural heritage tourism. For instance, emerging frameworks that integrate generative AI, gamification, and AR are enabling more adaptive and personalized experiences in heritage tourism. Such systems provide interactive storytelling, real-time feedback, and behavior prediction, resulting in visitor experiences that are more engaging and contextually responsive (Martusciello et al., 2025). Furthermore, mixed reality heritage performances (MRHPs), combining AR headsets with live theater, have been created as decolonizing tools that bring underrepresented or contested histories to life through immersive, emotional storytelling (Dima et al., 2024). These performances foster emotional connection and reflection, deepening visitors' appreciation of heritage. Moreover, AR navigation systems are being enhanced to incorporate multimodal content—such as audio, visuals, and text—and smart wayfinding using QR codes, as shown in prototype applications at the Han Yu heritage sites in China. These advancements enhance on-site learning and accessibility, while lessening dependence on physical infrastructure and minimizing the impact on delicate environments (Liu, 2021). Collectively, these emerging applications demonstrate that integrating AR with other technologies transforms the visitor experience—not merely by introducing new technology but by fostering more meaningful, inclusive, and sustainable ways to engage with heritage.

Despite the increasing attention given to AR in cultural heritage tourism, important gaps persist in examining how experiential satisfaction relates to the intention to continue using these technologies. An in-depth review of AR/VR tourism research shows that, while there is substantial focus on user experience and tourist behavioral intentions, there remains a clear shortage of studies that directly link user satisfaction with AR experiences to the intention to continue using such applications as a combined construct (Fan et al., 2022). Similarly, field experiments often focus on users' immediate experiences and short-term behavioral outcomes, but they rarely extend to examining how these experiences influence long-term usage of AR applications (K. Zhang et al., 2024). Taken together, these findings highlight a significant research gap: although early AR experiences in cultural heritage tourism have been widely studied, the complex relationship between user satisfaction and

the intention to continue using mobile AR apps over time has received limited attention. Bridging this gap is essential to deepen understanding of user loyalty and long-term engagement—an issue the next section aims to explore.

2.2. Expectation Confirmation Model (ECM)

In 1980, Oliver introduced the expectation confirmation theory (ECT) to study consumer satisfaction and repurchase behavior in marketing research. Through adapting ECT, Bhattacharjee developed the ECM in 2001 to study user satisfaction and continuous usage intention of technologies in information system research (Bhattacharjee, 2001). The ECM is considered a more effective approach for evaluating the success of an information system compared to assessing its initial acceptance through ECT which is based on the technology acceptance model (Davis, 1989). Firstly, the ECM postulates that the degree of confirmation influences users' perceptions about how technology is useful in supporting their tasks. Moreover, the ECM suggests that users feel satisfied when they perceive the technology as useful. Finally, the ECM posits that user satisfaction makes them use technology continuously (Bhattacharjee, 2001). The structural relationships hypothesized in the ECM have been empirically validated by researchers in recent studies within the context of various mobile apps, such as mobile learning (Dou et al., 2025), mobile banking services (Rabaa'i & ALMaati, 2021), and mobile accommodation booking (Park & Lee, 2023). However, limited attention has been given to mobile AR apps. This study defines (i) confirmation as the tourists' "perception of the congruence between expectation" of using the mobile AR app and "its actual performance"; (ii) perceived usefulness as their "perception of the expected benefits" of using the app; (iii) experiential satisfaction as their "feelings about prior usage" of the app; and (iv) continuance intention to use as their "intention to continue using" the app. Thus, the hypotheses are as follows:

- H1.** *Confirmation has a significant positive effect on perceived usefulness.*
- H2.** *Confirmation has a significant positive effect on experiential satisfaction.*
- H3.** *Perceived usefulness has a significant positive effect on experiential satisfaction.*
- H4.** *Perceived usefulness has a significant positive effect on continuance intention to use.*
- H5.** *Experiential satisfaction has a significant positive effect on continuance intention to use.*

2.3. Unified Theory of Acceptance and Use of Technology 2 (UTAUT2)

Research on new tourism technology must take into account determinants other than the ECM's core constructs to better understand whether users have a satisfactory experience when using the technology and their intention to use the technology repetitively (Zhong et al., 2015). Developed by Venkatesh, Thong, and Xu in 2012, the core constructs of UTAUT2 have undergone a substantial refinement and they consistently demonstrated a strong explanatory power in numerous studies of information technology adoption. As such, this study integrates the core constructs of UTAUT2 with ECM to investigate tourists' experiential satisfaction and their continuance usage intention of a mobile AR app. Although the integration of the ECM and UTAUT2 has been tested to gauge post-adoption behavior of general mobile apps (Tam et al., 2020; Islam & Azad, 2015), validating the integrated framework for AR technology in cultural heritage tourism remains scarce.

Five core constructs in UTAUT2 are integrated with the ECM in this study. First, performance expectancy is referred to as "the user's perception that using mobile AR apps will improve their travel planning and destination experience". This study treats perfor-

mance expectancy in UTAUT2 and perceived usefulness in the ECM as interchangeable when integrating the two models because both concepts refer to the users' belief that using technology will help them achieve desired outcomes or improve performance. Secondly, to encourage adoption, users should perceive using a new technology as effortless. Thus, this study defines effort expectancy as the "degree of ease associated with the use" of mobile AR apps. Studies have shown that effort expectancy influences users' satisfaction and their intention to continue using social mobile apps (Akdin et al., 2022) and mobile AR apps (Tam et al., 2020). Thirdly, this study defines social influence as "the degree to which an individual perceives that important others believe he or she should use" the mobile AR apps. Social influence was found to influence users' satisfaction in general mobile apps (S. Lee & Kim, 2021) and their continuance usage intention in mobile AR apps (Hung et al., 2021). Furthermore, individuals are more likely to use new technology when they perceive strong support from their surroundings, especially in terms of technical infrastructure (Venkatesh et al., 2012). However, there are conflicting findings regarding the relationship between facilitating conditions and users' intention to continue using mobile apps (Tam et al., 2020). This study defines facilitating conditions as "the degree to which an individual believes that an organizational and technical infrastructure exists to support use" of the mobile AR app. Lastly, individuals' sense of fun or enjoyment when using new technology in a non-work context is a key predictor of their intention to adopt it (Hong et al., 2017). Hedonic motivation was found to influence users' satisfaction (K. Kim et al., 2016). However, a previous study reported contradictory findings regarding the relationship between hedonic motivation and users' intention to continue using mobile AR apps (Tam et al., 2020). Hedonic motivation is defined as "the fun or pleasure derived from using" the mobile AR app. Thus, the hypotheses are as follows:

H6. *Effort expectancy has a significant positive effect on experiential satisfaction.*

H7. *Social influence has a significant positive effect on experiential satisfaction.*

H8. *Facilitating conditions have a significant positive effect on experiential satisfaction.*

H9. *Hedonic motivation has a significant positive effect on experiential satisfaction.*

H10. *Effort expectancy has a significant positive effect on continuance intention to use.*

H11. *Social influence has a significant positive effect on continuance intention to use.*

H12. *Facilitating conditions have a significant positive effect on continuance intention to use.*

H13. *Hedonic motivation has a significant positive effect on continuance intention to use.*

3. Methodology

3.1. Research Paradigm, Research Design, and Research Framework

This study adopts a positivist research paradigm, which assumes that knowledge is objectively derived from observable and measurable phenomena (Bhattacharjee, 2012). The positivist research paradigm aligns with the study's aim to empirically test hypothesized causal relationships derived from established theories, namely the ECM and UTAUT2 (Bhattacharjee, 2012). A quantitative research approach was employed, using a self-administered questionnaire distributed through an online survey to collect responses from participants. In line with this paradigm, a causal research design was adopted to investigate the cause-and-effect relationships among key constructs from the ECM and UTAUT2. Figure 1

illustrates the research framework. Firstly, the ECM was applied to investigate the structural relationships among confirmation, perceived usefulness, experiential satisfaction, and continuance intention to use (Research Objective 1). Then, the core constructs of UTAUT2 were integrated to investigate the determinants of tourists' experiential satisfaction (Research Objective 2) and continuance intention to use the mobile AR app (Research Objective 3).

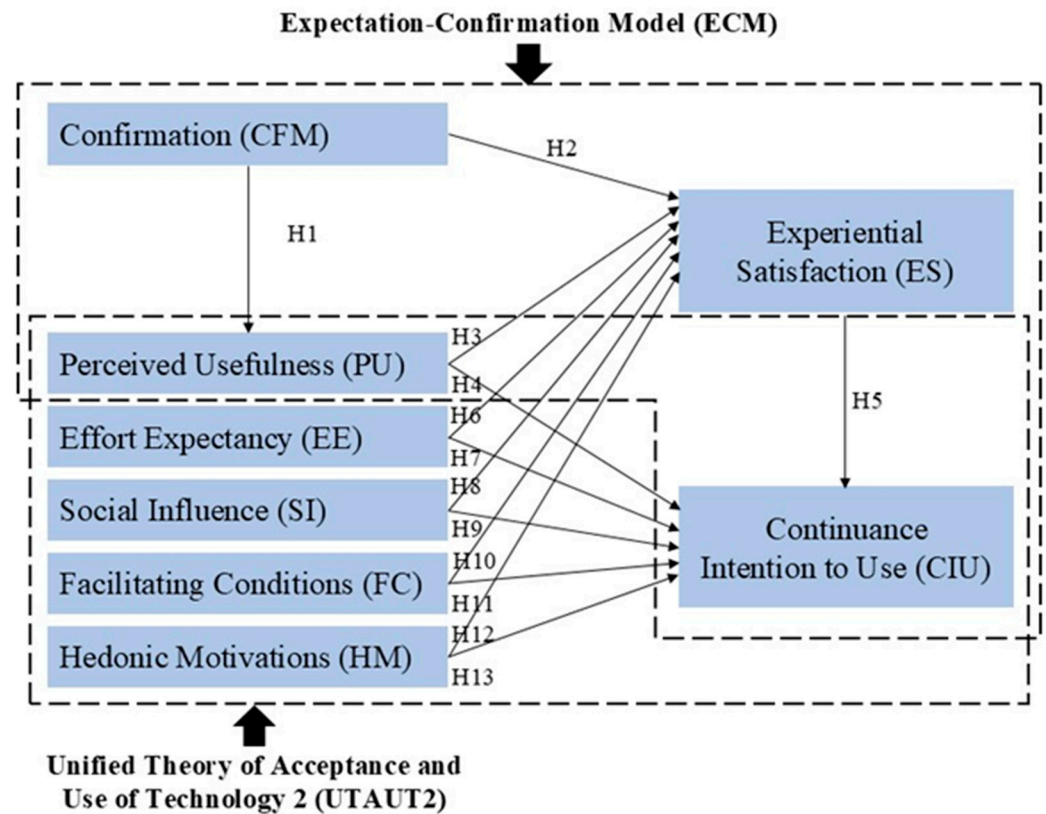


Figure 1. Research Framework.

3.2. Prototype Development

Called “When History Comes Alive”, a mobile AR app was developed for the survey respondents to get familiarized with its features and functions before answering the questionnaire. The mobile AR app took around five months to develop. It began with the selection of several physical artifacts from the People’s Museum in the first month, such as statues of legendary figures, traditional games, and ancient beauty accessories. In the following month, the chosen artifacts were digitized using the EinScan Pro HD handheld 3D scanner, which utilizes structured-light scanning and achieves an accuracy of up to 0.045 mm in handheld HD mode. The resulting 3D models were cleaned, decimated, and optimized using MeshLab and Blender in the third month to ensure they were suitable for rendering on mobile devices. In the following month, the AR app was developed using the Unity3D engine (version 2021.3 LTS) in combination with the Vuforia Engine SDK (version 10.x). Image target tracking was implemented to anchor the virtual models to printed images of the physical artifacts. The optimized 3D models, exported in .FBX format, were imported into Unity and linked to their corresponding image markers. In the last month, the app was finalized and deployed on Android devices, enabling real-time interaction with the virtual artifacts through mobile-based AR. When users download the mobile AR app into their smartphone, they must scan the respective QR code and AR marker to view virtual artifacts being overlaid onto the real-world environment through their smartphone

screens, allowing real-time interaction and engagement. Figure 2 shows the mobile AR app prototype.



Figure 2. “When History Comes Alive” Mobile AR App Prototype.

3.3. The UNESCO World Heritage City of George Town and Melaka

George Town and Melaka were jointly inscribed as UNESCO World Heritage Sites in 2008 in recognition of their exceptional cultural and historical significance. Being prominent cultural heritage tourism destinations, these cities continue to draw large numbers of both domestic and international visitors each year. However, the growing number of visitors has raised concerns about overcrowding, physical wear and tear on fragile heritage structures, and the potential for partial or complete site closures. In this context, the mobile AR app developed in this study presents a potential solution by allowing travelers to engage meaningfully with virtual reconstructions of artifacts and heritage sites, without the need for direct physical interaction with the originals. This digital approach not only enhances the visitor experience and satisfaction but also promotes sustainable tourism by minimizing physical impact on cultural assets and offering alternative means of exploration and interpretation.

3.4. Survey Development, Data Collection and Analysis

The questionnaire consists of Part A—Social-Demographic Profile and Travel Behavior, and Part B—Experiential Satisfaction and Continuance Intention to Use with 46 items in total: CM (3), PU (7), EE (6), SI (5), FC (4), HM (4), ES (9), and CIU (6). The survey items in Part B were adapted from previous studies, measured using a seven-point scale, with 1 = “strongly disagree” to 5 = “strongly agree”. The survey instrument was validated by several subject matter experts to ensure content clarity and its relevance to the study. Next, a pilot study test was conducted among fifty respondents and the Cronbach alpha of all the constructs surpassed the minimum threshold of 0.75 in the reliability analysis. Ethical clearance for the survey instruments was granted by the Ethics Committee of Multimedia University. A cross-sectional online survey was conducted using a convenience sampling technique where the survey link was shared through the Facebook page of the Penang Institute and Tourism Melaka which are the official platforms for the local tourism authorities to disseminate travel updates and stay connected with followers (who are the actual and potential tourists in George Town and Melaka). A protocol was established with

the local tourism authorities to obtain authorization for data collection from their social media pages. A non-probability convenience sampling technique was applied as it allows collecting many responses quickly and cost-effectively. Written consent was contained from the respondents for voluntary participation in the study. The identity of the respondents was treated anonymously, and their responses were kept private and confidential due to ethical concerns. A total of 450 responses were collected within a six-month online survey. All the responses were first scrutinized to ensure the absence of missing values or outliers before data analysis. The sample size of 450 fulfilled the minimum sample size of 384 suggested by Krejcie and Morgan based on the target population size (28.69 million domestic tourists in both Melaka and George Town in 2023) (Krejcie & Morgan, 1970). A larger sample size is consistent with earlier studies on users’ adoption of mobile AR applications in cultural heritage tourism (Jung et al., 2015, 2018). The SmartPLS 4.0 software application for variance-based structural equation modeling utilizing the partial least squares approach (PLS-SEM) was used to analyze the data due to its powerful ability used for theoretical models with complex causal relationships between variables and its applications are proven to be robust in many fields and disciplines (Hair et al., 2012).

4. Results and Findings

4.1. Descriptive Analysis

Socio-Demographic Profile and Travel Behavior

The study attracted more responses from young adults within the age groups of 21–30 (60.67%) and 31–40 (20.44%). There was a strong representation of females (63.56%) over males (36.44%). The top three reasons for travel among the respondents were holiday, leisure, or relaxation (76.22%), visiting friends or relatives (53.33%), and shopping (47.78%). Social media (78.00%) emerged as the most widely used travel planning tool, followed by search engines (54.89%), online travel sites (43.78%), and travel-specific mobile apps (36.89%), reflecting a clear preference of digital source and app-based tools in digital trip planning as compared to conventional tools. Most respondents reported bringing a smartphone (99.11%) during their trip, making it the most used digital device among travelers. Internet access was widely available, with 97.56% of participants indicating that they had an active connection during their trip. In terms of connectivity methods, 60.67% relied on a personal mobile data plan, while 35.56% reported using both mobile data and Wi-Fi. Only 1.33% used Wi-Fi exclusively, and 2.44% reported having no internet connection during their trip. Table 1 summarizes the socio-demographic profile and travel behavior of the respondents.

Table 1. Socio-Demographic Profile and Travel Behavior.

Profile	Frequency (<i>n</i> = 450)	Percentage (100%)
Gender		
Male	164	36.44
Female	286	63.56
Age		
Below 21 years old	33	7.33
21–30 years old	273	60.67
31–40 years old	92	20.44
41–50 years old	36	8.00
51–60 years old	12	2.67
61 years old and above	4	0.89

Table 1. *Cont.*

Profile	Frequency (<i>n</i> = 450)	Percentage (100%)
Purposes of Traveling		
Shopping	215	47.78
History and culture	209	46.44
Visiting friends/relatives	240	53.33
Holiday/leisure/relaxation	343	76.22
Entertainment/sporting events	132	29.33
Travel Planning Tool Used		
Social media (Instagram, Facebook, TikTok, YouTube)	351	78.00
Search engine (browsing Google, Yahoo, Bing)	247	54.89
Online travel sites (Booking.com, TripAdvisor, Expedia, Airbnb)	197	43.78
Travel-specific mobile apps	166	36.89
Printed travel books/magazines/leaflets/brochures	63	14.00
I do not plan when traveling	74	16.44
Brought-Along Digital Devices		
Tablet PC	55	12.22
Smartphone	446	99.11
Laptop/notebook PC	89	19.78
Others	12	2.67
Availability of Internet Connection		
Yes	439	97.56
No	11	2.44
Data Connectivity Plan Mostly Used		
Personal mobile data plan	273	60.67
Wi-Fi connection	6	1.33
Both mobile data and Wi-Fi	160	35.56
No internet connection	11	2.44

4.2. Central Tendency, Dispersion, and Normality

The results of mean, standard deviation, skewness, and kurtosis of the data are shown in Table 2. Based on a seven-point scale, the highest mean of 5.811 was reported by HM, followed by PU (5.762), FC (5.752), EE (5.742), ES (5.683), CIU (5.634), CFM (5.516), and SI (5.314). The mean values indicate that the respondents showed a moderate to strong agreement on the items measuring the constructs. Next, standard deviation was deemed desirable as the values were close to 1, indicating the data points were relatively consistent and concentrated around the mean. Skewness and kurtosis were also assessed to test normality of data. Skewness and kurtosis were considered desirable as the values fell within the tolerable range of ± 1 and ± 2 , respectively (Hair et al., 2022), and proximate to zero (George & Mallery, 2019), signifying the data was distributed normally and fit for analysis.

Table 2. Mean, Standard Deviation, Skewness, and Kurtosis.

Construct	No. of Items	Mean	Standard Deviation	Excess Kurtosis	Skewness
CFM	3	5.516	1.0644	−0.535	0.114
PU	7	5.762	1.0568	−0.794	0.520
EE	6	5.742	1.0580	−0.805	0.713
SI	4	5.314	1.3270	−0.864	0.656

Table 2. *Cont.*

Construct	No. of Items	Mean	Standard Deviation	Excess Kurtosis	Skewness
FC	4	5.752	1.0958	−0.763	0.307
HM	4	5.811	1.0262	−0.729	0.221
ES	7	5.683	1.1041	−0.887	1.026
CIU	6	5.634	1.1999	−0.880	0.788

4.3. Reflective Measurement Model Evaluation

During the initial phase of the SEM-PLS approach, a measurement model was established to test the dataset for reliability and for both convergent and discriminant validity using a range of assessment criteria. The factor loading of all the indicators, ranging from 0.738 to 0.948, surpassed the minimum threshold of 0.708, showing a strong relationship between the indicators and their respective constructs (Hair et al., 2021). Next, the average variance extracted (AVE) of all the constructs, ranging from 0.707 to 0.879, exceeded the minimum threshold of 0.50 or, in other words, the constructs explained a considerably large portion of the variance of their respective indicators collectively, suggesting that the measurement model has a robust convergent validity (Sarstedt et al., 2021). Then, composite reliability of all the constructs, ranging from 0.861 to 0.964, far exceeded the minimum threshold of 0.70, suggesting an exceptionally high internal consistency as the indicators are highly correlated and consistently measuring their respective constructs (Hair et al., 2021). Table 3 presents the details.

Table 3. Outer Loadings, Reliability, and Validity Statistics for Measurement Model.

Constructs	Indicators	Outer Loadings	Composite Reliability (CR)	Cronbach's Alpha (CA)	Average Variance Extracted (AVE)
CFM	CFM1	0.929	0.918	0.918	0.858
	CFM2	0.935			
	CFM3	0.916			
PU	PU1	0.863	0.947	0.947	0.758
	PU2	0.898			
	PU3	0.871			
	PU4	0.877			
	PU5	0.872			
	PU6	0.824			
	PU7	0.888			
EE	EE1	0.884	0.950	0.950	0.800
	EE2	0.885			
	EE3	0.916			
	EE4	0.902			
	EE5	0.865			
	EE6	0.914			
SI	SI1	0.925	0.903	0.905	0.784
	SI2	0.936			
	SI3	0.927			
	SI4	0.738			
FC	FC1	0.859	0.861	0.861	0.707
	FC2	0.871			
	FC3	0.843			
	FC4	0.787			
HM	HM1	0.927	0.955	0.954	0.879
	HM2	0.946			
	HM3	0.930			
	HM4	0.948			

Table 3. Cont.

Constructs	Indicators	Outer Loadings	Composite Reliability (CR)	Cronbach's Alpha (CA)	Average Variance Extracted (AVE)
ES	ES1	0.903	0.956	0.955	0.787
	ES2	0.899			
	ES3	0.910			
	ES4	0.864			
	ES5	0.856			
	ES6	0.899			
	ES7	0.878			
CIU	CIU1	0.904	0.964	0.963	0.846
	CIU2	0.932			
	CIU3	0.932			
	CIU4	0.939			
	CIU5	0.916			
	CIU6	0.894			

Lastly, discriminant validity of the measurement model was assessed using Fornell and Larker test and heterotrait–monotrait (HTMT) techniques (Sarstedt et al., 2021). Table 4 shows the results of the discriminant validity test using the Fornell and Larker criterion. For all the constructs, the square root of the AVE (highlighted in bold) is greater than their correlations with any other construct, verifying that each construct in the measurement model is sufficiently distinct from other constructs, thus displaying satisfactory discriminant validity (Fornell & Larcker, 1981). Another new criterion for assessing discriminant validity is using the HTMT ratio. Table 5 shows the HTMT ratios, ranging from 0.667 to 0.889, which are below the maximum threshold of 0.90 and neither the lower nor upper 90% bootstrap confidence interval of HTMT includes a value of 1, further confirming that the discriminant validity of the measurement model was achieved and findings were robust (Henseler et al., 2015).

Table 4. Discriminant Validity using the Fornell and Larcker Criterion.

	CFM	PU	EE	SI	FC	HM	ES	CIU
CFM	0.928							
PU	0.778	0.870						
EE	0.756	0.804	0.894					
SI	0.666	0.702	0.681	0.886				
FC	0.674	0.739	0.816	0.667	0.841			
HM	0.679	0.807	0.775	0.687	0.784	0.937		
ES	0.807	0.828	0.889	0.737	0.815	0.863	0.887	
CIU	0.745	0.790	0.742	0.757	0.741	0.790	0.870	0.921

Table 5. Discriminant Validity using the HTMT Ratio.

	CFM	PU	EE	SI	FC	HM	ES	CIU
CFM								
PU	0.778							
EE	0.756	0.804						
SI	0.666	0.702	0.681					
FC	0.674	0.739	0.816	0.667				
HM	0.679	0.807	0.775	0.687	0.784			
ES	0.807	0.828	0.889	0.737	0.815	0.863		
CIU	0.745	0.790	0.742	0.757	0.741	0.790	0.870	

4.4. Structural Model Evaluation

While the criteria for discriminant validity were satisfied, latent collinearity, resulting from high intercorrelations among constructs within the structural model, may compromise the clarity of the findings and result in misinterpretation (Kock & Lynn, 2012). Table 6 shows the results of the latent collinearity test. The inner inflation factors (VIFs) of all constructs, ranging from 2.088 to 4.189, were far below the recommended threshold of 10, suggesting that latent collinearity is not a major concern in the structural model and that the relationships between the constructs were quite well-defined and distinct (Kock & Lynn, 2012).

Table 6. Collinearity assessment.

	CIU	ES	PU
CFM		2.481	1.000
EE	4.189	3.505	
ES	5.665		
FC	2.631	2.598	
HM	3.719	3.172	
PU	3.320	3.572	
SI	2.097	2.088	

4.5. Hypothesis Testing

The R^2 coefficient that measures the proportion of the variation in a dependent variable that is explained by the independent variables was tested and the strength can be either substantial (0.75), moderate (0.50), or weak (0.25) (Cohen, 2013). Also, predictive relevance, or Q^2 , was assessed to measure whether the structural model demonstrates adequate predictive relevance accuracy, such that the closer the Q^2 and R^2 , the higher the predictive relevance accuracy (Cohen, 2013). Table 7 shows R^2 and Q^2 of the dependent variables. The R^2 of PU was 0.527%, suggesting a relatively substantial proportion of variance (52.7%) in perceived usefulness was explained by confirmation alone and the Q^2 (0.523) was close to R^2 , suggesting high predicting relevance accuracy of the path. The R^2 of ES was 0.837%, suggesting a highly substantial proportion of variance (83.7%) in experiential satisfaction was explained by the independent variables and the Q^2 (0.835) was close to R^2 , suggesting high predicting relevance accuracy of the structural model. The R^2 of CIU was 0.753%, suggesting a substantial proportion of variance (75.3%) in continuance usage intention was explained by the independent variables and the Q^2 (0.690) and was close to R^2 , suggesting high predicting relevance accuracy of the structural model. Next, the standardized root mean square residual (SRMR) on both saturated and estimated models was analyzed, where a value less than 0.08 indicates a good fit (Hu & Bentler, 1999). Table 8 shows that the SRMR coefficients for saturated and estimated models were both 0.076, confirming a good fit between the proposed model and the observed data.

Table 7. R^2 and Q^2 .

	R^2	R^2 Adjusted	Q^2
CIU	0.753	0.750	0.690
ES	0.837	0.835	0.827
PU	0.527	0.526	0.523

Table 8. SRMR Model fit.

	Original Sample (O)	Sample Mean (M)
Saturated Model	0.076	0.036
Estimated Model	0.076	0.036

Table 9 shows the outcomes of hypotheses testing. Except Hypotheses 3, 11, and 13, all other hypotheses were found to be statistically significant. An assessment of the effect size was needed as the p -value only tested the existence of effect between variables (Sullivan & Feinn, 2012). f^2 can be used to calculate effect size, with values ranging from 0.35 (large), 0.15 (medium) to 0.02 (small) (Sullivan & Feinn, 2012).

Table 9. Hypothesis Testing.

	Relationship	Std. Beta	Std. Error	t-Value	p-Value	Decision	f^2	Effect Size
H1	CM > PE	0.726	0.03	23.89	0.000	Supported	1.113	Large
H2	CM > ES	0.185	0.046	3.999	0.000	Supported	0.085	Small
H3	PU > ES	0.054	0.048	1.121	0.131	Not supported	0.005	Small
H4	PU > CIU	0.178	0.064	2.797	0.003	Supported	0.039	Small
H5	ES > CIU	0.531	0.077	6.937	0.000	Supported	0.201	Medium
H6	EE > ES	0.343	0.061	5.596	0.000	Supported	0.206	Medium
H7	EE > CIU	−0.127	0.066	1.936	0.026	Supported	0.016	Small
H8	SI > ES	0.079	0.034	2.36	0.009	Supported	0.019	Small
H9	SI > CIU	0.208	0.057	3.635	0.000	Supported	0.084	Small
H10	FC > ES	0.074	0.043	1.702	0.044	Supported	0.013	Small
H11	FC > CIU	0.065	0.056	1.17	0.121	Not supported	0.007	Small
H12	HM > ES	0.309	0.05	6.133	0.000	Supported	0.185	Medium
H13	HM > CIU	0.097	0.064	1.516	0.065	Not supported	0.01	Small

5. Discussion

The first research objective examines how the main constructs in the ECM relate structurally. Four hypotheses (H1: CFM $\rightarrow$ PU; H2: CFM $\rightarrow$ ES; H4: PU $\rightarrow$ CIU; H5: ES $\rightarrow$ CIU) were supported, except H3 (PU $\rightarrow$ ES). During the pre-adoption stage, tourists form expectations about mobile AR apps based on app descriptions and user-generated reviews. After interacting with the app, users evaluate its actual performance relative to their initial expectations, resulting in either confirmation or disconfirmation. This cognitive appraisal influences their perceived usefulness and experiential satisfaction, which both shape their intention to continue using the app. But the direct relationship between perceived usefulness and experiential satisfaction was found to be statistically non-significant. Mobile AR apps in the tourism context are typically categorized within the lifestyle and leisure domain, as they are used voluntarily by visitors to enrich their travel experiences (Jumaan et al., 2020). Mobile apps which emphasize social interactions and enjoyment values have a more influential effect than that of perceived usefulness in facilitating a higher degree of users' satisfaction (C. K. Huang et al., 2019). This contrasts with goal-oriented or productivity-focused mobile apps, which support users in performing essential daily tasks and aim to enhance efficiency—contexts where perceived usefulness tends to play a more dominant role (Z. Huang & Benyoucef, 2023; J. Kim et al., 2019). Thus, Research Objective 1 is achieved.

The second research objective seeks to investigate the determinants of experiential satisfaction in using mobile AR apps. Except perceived usefulness, all other constructs were found to have a significant positive effect ($p < 0.05$) on experiential satisfaction, with effort expectation as the strongest predictor ($\beta = 0.343$), followed by hedonic motivation ($\beta = 0.309$), confirmation of expectations ($\beta = 0.185$), social influence ($\beta = 0.079$), and facilitating conditions ($\beta = 0.074$). Combining constructs from UTUAT2 into the ECM contributes an exceptionally high predictive power for experiential satisfaction and continuance intention to use, such that all independent variables together explained 83.7 percent ($R^2 = 0.837$) of the variance in experiential satisfaction, higher than the original ECM model ($R^2 = 0.678$) (Bhattacharjee, 2001). Thus, Research Objective 2 is achieved.

The third research objective aims to identify the determinants of continuance intention to use mobile AR apps. Two constructs were found to have a significant positive effect ($p < 0.05$) on continuance intention to use, with social influence being a stronger predictor ($\beta = 0.208$) than perceived usefulness ($\beta = 0.178$). Combining UTAUT constructs into the ECM contributes a substantially high predictive power for continuance usage intention, such that all variables together explained 75.3 percent ($R^2 = 0.753$) of the variance in continuance usage intention, higher than the original ECM model ($R^2 = 0.639$) (Bhattacharjee, 2001) and Saima et al. (2024) with $R^2 = 0.535$. On a contradictory note, effort expectancy exerts a significant negative impact on continuance usage intention ($\beta = -0.127$). The inverse relationship may be attributed to the respondents' familiarity with digital tools, as most were young and they likely have sufficient experience in using mobile apps for travel information seeking (Humbani & Wiese, 2018), reducing perceived difficulty in using the mobile AR app (Cheng et al., 2020). Users could ignore the level of complexity they might perceive in using the apps (Alalwan, 2020; Shaw & Sergueeva, 2019). Instead, users focus more on the benefits these apps provide, which serve as key motivators for continuance usage intention. On the other hand, the findings reveal there is an absence of a significant relationship of hedonic motivation and facilitating conditions toward continuance usage intention. The hedonic attributes of AR mobile apps, such as playfulness, enjoyment, and pleasure, do not significantly influence continuance usage intention in the long run (Tam et al., 2020) but only immediate usage experience. In fact, behavioral cues from friends and family have a stronger influence on users' intention to continue using a mobile AR app (Beldad & Hegner, 2018). Lastly, access to technical and human support does not influence continuous usage intention because consumers today have adequate experience in using various mobile apps for different purposes in their daily lives (Tam et al., 2020). Improved digital literacy attributable to user-friendly mobile apps' functions and interfaces (Ho et al., 2021) and widespread availability of reliable internet connectivity (Rabaa'i & ALMaati, 2021) make learning and using mobile AR apps faster and easier.

In short, the results align with prior research indicating that experiential satisfaction significantly influences continued technology use (e.g., Bhattacharjee, 2001; Tam et al., 2020). However, unlike previous studies that examined ECM or UTAUT2 separately, this study demonstrates the enhanced explanatory power when both models are integrated in the context of mobile AR tourism. This finding extends the work of Chen et al. (2023) by validating the combined model in a cultural heritage setting.

6. Conclusions

6.1. Theoretical and Practical Contributions of the Study

The key theoretical contribution this study offers is by proposing and validating an integrated model of ECM-UTAUT2 to examine the success of a mobile AR app in a tourism context. In view of an increasing application of AR used to enhance cultural heritage experiences, the integrated model provides a more comprehensive understanding of users' experiential satisfaction and continuance usage intention than the original ECM. The research framework captures and links two key phases: the pre-adoption expectations, guided by UTAUT2 constructs—both internal and external constructs—and the post-adoption evaluation, based on ECM constructs. Thus, the integrated model provides a comprehensive understanding of how users develop and sustain engagement with AR technology in tourism. The findings confirm that experiential satisfaction plays a central role in users' continued use, as proven by prior research. The findings also highlight that UTAUT2 constructs significantly improve the explanatory power of experiential satisfaction and continuance usage intention of mobile AR apps.

The findings of this study provide insightful practical implications to mobile AR app developers, tourism businesses, and authorities. Relevant stakeholders should ensure the mobile AR app used for cultural heritage tourism aligns users' expectations with the app's actual performance, as this congruence promotes users' satisfaction and continuous usage. Information about the key features and benefits of the app should be made clear to enhance visitors' expectation setting and reduce frustration prior to using the app. Cultural heritage sites and tourist information centers should promote and support user adoption by offering easy-to-follow video guides and responsive assistance to help visitors in installing and using the app. Mobile AR app developers should release timely updates and regularly collect feedback through reviews and user satisfaction surveys to fix issues. Doing so can improve users' perception that using the app is satisfying as it is able to enhance their travel experience, which are the key drivers of continuance usage intention.

In conclusion, this study underscores the strategic significance of mobile AR apps in the tourism sector, positioning them not merely as attention-grabbing novelties but as powerful tools for enhancing cultural heritage experiences and fostering sustained user engagement. By integrating ECM and UTAUT2 frameworks, the research provides a robust model that captures both the anticipatory and evaluative dimensions of user interaction with AR technology. The findings affirm that experiential satisfaction is pivotal to continued usage and that aligning user expectations with actual app performance is essential for long-term success. For tourism stakeholders, this means investing in intuitive design, clear communication of app benefits, and ongoing support mechanisms. When thoughtfully implemented, mobile AR apps can enrich visitors' experiences, deepen cultural appreciation, and drive repeat engagement, ultimately contributing to the sustainable growth and digital transformation of the tourism industry.

To translate these findings into actionable recommendations, several global AR initiatives present adaptable strategies that could enhance heritage tourism in Malaysia. For instance, Greece's COSMOTE CHRONOS project employs AR and AI to digitally reconstruct ancient ruins—an approach that could be effectively applied to visualize lost historical landmarks like A'Famosa in Melaka or Fort Cornwallis in George Town. Next, the Tirtha platform in India creates 3D heritage models using crowdsourced images—a technique that could be adapted to digitally preserve traditional Malay houses, Bornean long-houses, and colonial-era buildings. Furthermore, Saudi Arabia's wearable AR tours in Al-Ula demonstrate the potential to enhance site navigation and multilingual storytelling in culturally rich Malaysian cities. Moreover, Denmark's Hololink demonstrates how straightforward, map-based AR can enhance accessibility to interactive content in museums and visitor centers. Meanwhile, China's OperARtistry illustrates how AR can help preserve intangible heritage by teaching traditional practices like opera makeup—providing a valuable model for safeguarding Malaysian customs such as batik making, wayang kulit, and traditional dance. These international examples provide concrete, adaptable strategies for enhancing Malaysia's heritage tourism sector through more inclusive, accessible, and community-driven AR apps.

6.2. Limitations of the Study and Suggestions for Future Studies

There are several limitations of this study. First, a convenience sampling technique was employed, targeting participants who were most accessible or willing to respond. However, this approach may introduce sampling bias and limit the generalizability of the findings to the broader tourist population. Thus, a mixed-mode approach (combining online and offline surveys) and probability random sampling are recommended in future studies to improve generalizability. Second, this study employed a quantitative approach; therefore, future research could adopt a qualitative methodology to gain a more holistic

and in-depth understanding of tourists' behavior in the realm of AR tourism technology, which is inherently complex and continuously evolving. Next, this study employed a cross-sectional design, capturing data at a single point of time. However, as user behavior with technology evolves, a longitudinal approach in future research would provide deeper insights to better understand long-term usage patterns and develop strategies to enhance retention. Furthermore, future research can extend the integrated model by incorporating other relevant antecedents such as innovativeness, perceived value, etc. Last but not least, a similar study can be validated at other cultural heritage sites in Malaysia or within the region as this study only focuses George Town and Melaka.

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