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Augmented Reality Cartography and Urban Economic Dynamics: Quantifying the Synergies Between 3D Mapping Technologies and Cultural Event Tourism

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Abstract

This study investigates the adoption and economic impact of Augmented Reality (AR) cartography in cultural tourism contexts. Drawing on the Technology Acceptance Model and cultural tourism literature, we examine how perceived usefulness, ease of use, and enjoyment influence AR adoption, cultural event experiences, and local economic outcomes. The study employs a quantitative approach, utilizing structural equation modeling to analyze data collected from 487 participants at a major cultural event. Findings reveal that AR cartography adoption significantly enhances cultural event experiences and increases local business spending, both directly and indirectly through extended length of stay. Demographic factors, particularly age, gender, and education level, moderate these relationships. Notably, the study demonstrates that AR use creates a virtuous cycle of improved experiences, longer stays, and increased spending. This research contributes to the literature by providing empirical evidence for the economic benefits of AR in cultural tourism, extending beyond previous studies that focused primarily on user satisfaction and behavioral intentions. It also offers practical implications for destination managers and policymakers, suggesting that investment in AR infrastructure could yield substantial economic returns. The study opens new avenues for research into the role of immersive technologies in driving sustainable economic development through cultural tourism.

Keywords: Augmented Reality (AR) cartography, cultural tourism, economic impact, technology acceptance model, visitor experience

1. Introduction

In the rapidly evolving landscape of urban development and digital innovation, the convergence of augmented reality (AR) cartography and cultural event tourism presents a compelling area of study with significant implications for urban economic dynamics. As cities worldwide strive to enhance their competitiveness and attract both residents and visitors, the integration of cutting-edge technologies with traditional cultural offerings has emerged as a potent strategy for economic growth and urban revitalisation (Gretzel et al., 2015). This research focuses on the synergistic relationship between 3D mapping technologies and cultural event tourism, with a particular emphasis on quantifying their economic impact in the context of Hanoi, Vietnam—an emerging market at the forefront of digital transformation in Southeast Asia.

The advent of augmented reality has revolutionised the way individuals interact with their surroundings, offering immersive experiences that blend digital information with the physical world. In the realm of urban tourism, AR applications have demonstrated considerable potential for enhancing visitor experiences, increasing engagement, and driving economic activity (Jung et al., 2015). Concurrently, cultural events have long been recognised as catalysts for local economic development, attracting tourists, stimulating spending, and fostering community pride (Getz and Page, 2016). The intersection of these two domains—AR technology and cultural event tourism—represents a nascent yet promising field of inquiry that warrants in-depth exploration.

Recent studies have begun to elucidate the potential of AR in tourism contexts. For instance, tom Dieck and Jung (2018) highlighted the capacity of AR to enhance cultural heritage experiences, while Cranmer et al. (2020) demonstrated its effectiveness in improving wayfinding and information accessibility for urban tourists. However, the specific economic implications of integrating AR cartography with cultural event tourism remain understudied, particularly in the context of emerging markets such as Vietnam.

Vietnam, and notably its capital city Hanoi, presents an intriguing case study for this research. As a rapidly developing economy with a rich cultural heritage, Vietnam has embraced digital technologies as a means of economic advancement (Nguyen et al., 2019). Hanoi, with its blend of ancient traditions and modern aspirations, serves as a microcosm of the country's digital transformation. The city's efforts to leverage technology in promoting its cultural events offer a unique opportunity to examine the economic dynamics at play when augmented reality intersects with urban tourism initiatives.

This study aims to bridge the existing knowledge gap by quantifying the economic impact of 3D mapping applications on local businesses during Hanoi's cultural events. By employing a rigorous quantitative approach, we seek to provide empirical evidence of the synergies between AR cartography and cultural event tourism, thereby contributing to both academic discourse and practical urban economic strategies. The significance of this research lies in its potential to inform policy decisions and business strategies in emerging markets seeking to harness digital technologies for economic growth. By elucidating the mechanisms through which AR cartography influences tourist behaviour and local business performance during cultural events, this study offers valuable insights for urban planners, event organisers, and technology developers alike. Moreover, the novelty of this research stems from its integrated approach, combining elements of digital geography, urban economics, and cultural tourism studies. While previous research has examined these areas in isolation, our study provides a holistic analysis of their interplay, offering a more nuanced understanding of the complex relationships at work in the modern urban economy.

As cities worldwide grapple with the challenges and opportunities presented by digital transformation, the findings of this study will contribute to a growing body of knowledge on smart city initiatives and their economic implications. By focusing on the specific case of Hanoi, we aim to shed light on the unique dynamics at play in emerging markets, where rapid technological adoption intersects with rich cultural traditions and evolving urban landscapes.

2. Literature Review

2.1 Theretical Foundations

2.1.1 Urban Economic Theory

Urban economic theory provides a crucial framework for understanding the dynamics of economic activities within cities. Central to this field is the concept of agglomeration economies, which posits that the concentration of economic activities in urban areas leads to increased productivity and innovation (Glaeser, 2010). In the context of our study, this theory helps explain why cultural events and technological innovations tend to cluster in urban centres, creating synergies that drive economic growth.

Recent developments in urban economic theory have increasingly focused on the role of knowledge spillovers and human capital in driving urban growth. Florida et al. (2017) argue that cities with diverse, creative populations are more likely to attract innovative industries and experience economic growth. This perspective is particularly relevant to our study, as it suggests that the integration of AR technologies with cultural events could enhance a city's appeal to creative professionals and tourists alike, potentially stimulating economic activity.

Moreover, the New Economic Geography model, pioneered by Krugman (1991) and further developed by scholars like Fujita and Thisse (2013), emphasizes the importance of increasing returns to scale and transportation costs in shaping urban economic landscapes. This model provides a theoretical basis for understanding how technological innovations like AR cartography might alter the economic geography of cities by reducing information asymmetries and enhancing accessibility to cultural events.

2.1.2. Digital Innovation and Technological Acceptance Models

To understand the adoption and impact of AR technologies in urban settings, we draw upon theories of digital innovation and technology acceptance. The Technology Acceptance Model (TAM), initially proposed by Davis (1989) and subsequently extended by Venkatesh and Davis (2000), offers a framework for predicting user adoption of new technologies based on perceived usefulness and ease of use. In the context of AR applications for cultural tourism, this model helps explain factors influencing user engagement and the potential economic implications of widespread adoption.

Building on TAM, the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003) incorporates additional factors such as social influence and facilitating conditions. This more comprehensive model is particularly relevant to our study, as it accounts for the social and cultural contexts that might influence the adoption of AR technologies in diverse urban environments like Hanoi.

Recent work by Rauschnabel (2018) has further adapted these models specifically for AR technologies, proposing the AR Acceptance Model (ARM). This model incorporates unique aspects of AR experiences, such as wearability and augmentation quality, providing a more nuanced framework for understanding user acceptance of AR applications in tourism contexts.

2.1.3. Cultural Tourism and Event Impact Theories

The theoretical underpinnings of cultural tourism and event impact studies are essential for our research. The concept of cultural capital, introduced by Bourdieu (1986) and applied to tourism by scholars like Richards (2018), helps explain the value attributed to cultural experiences and how this translates into economic activity. This theory suggests that AR technologies could potentially enhance the cultural capital of events, thereby increasing their economic impact.

Event impact theories, such as those developed by Getz (2008) and refined by Crompton and McKay (1994), provide frameworks for assessing the economic, social, and cultural impacts of events on host communities. These theories typically categorize impacts into direct, indirect, and induced effects, offering a comprehensive approach to measuring the full economic implications of cultural events enhanced by AR technologies.

More recently, the Experience Economy model, proposed by Pine and Gilmore (1998) and applied to tourism by scholars like Oh et al. (2007), emphasizes the importance of creating memorable and immersive experiences. This theory is particularly relevant to our study, as AR technologies have the potential to significantly enhance the experiential aspects of cultural tourism, potentially leading to increased economic benefits.

By integrating these theoretical foundations – urban economic theory, digital innovation and technology acceptance models, and cultural tourism and event impact theories – our study aims to develop a comprehensive framework for understanding and quantifying the economic impact of AR-enhanced cultural events in urban settings. This interdisciplinary approach addresses a gap in the current literature, which has often treated these theoretical domains in isolation. Our research contributes to the field by proposing a unified theoretical model that captures the complex interactions between technological innovation, cultural experiences, and urban economic dynamics in the context of emerging markets like Vietnam.

2.2. Augmented Reality in Urban Contexts

2.2.1. Evolution of AR Technologies in Cities

The evolution of AR technologies in urban settings has been rapid and transformative. Early applications of AR in cities were primarily limited to simple location-based services and basic visual overlays (Azuma et al., 2001). However, advancements in mobile computing, computer vision, and geospatial technologies have dramatically expanded the capabilities and applications of AR in urban environments.

Ramos et al. (2018) trace the development of urban AR from early prototypes to sophisticated systems capable of real-time environmental understanding and contextual information delivery. They highlight the shift from marker-based AR to markerless systems, which has significantly broadened the potential applications in urban settings. This evolution has enabled more seamless integration of digital information with the physical urban landscape, creating new possibilities for navigation, tourism, and urban planning (Pak et al., 2017).

Recent years have seen the emergence of large-scale AR platforms specifically designed for urban environments. For instance, Sato et al. (2016) describe the development of city-scale AR systems that leverage existing urban infrastructure to create persistent and shared AR experiences. These advancements have paved the way for more immersive and interactive urban AR applications, particularly in the realms of cultural heritage and tourism (tom Dieck and Jung, 2018).

2.2.2. 3D Mapping Applications: Current State and Future Prospects

3D mapping applications represent a crucial component of AR technologies in urban contexts. These applications have evolved from basic 3D models to highly detailed, interactive representations of urban environments. Billen et al. (2015) provide a comprehensive overview of the current state of 3D urban mapping, highlighting the integration of various data sources including LiDAR, photogrammetry, and crowdsourced information to create accurate and detailed 3D city models. Recent advancements in real-time 3D reconstruction and simultaneous localization and mapping (SLAM) technologies have further enhanced the capabilities of AR mapping applications. Kamel Boulos et al. (2017) discuss how these technologies enable dynamic updating of 3D maps, allowing for more accurate and responsive AR experiences in rapidly changing urban environments.

Looking to the future, several promising developments are emerging. Alvarez León and Rosen (2020) explore the potential of integrating AI and machine learning with 3D mapping to create more intelligent and adaptive urban AR systems. Additionally, the advent of 5G networks promises to enhance the capabilities of AR applications by enabling faster data transmission and more complex real-time computations (Elbamby et al., 2018).

2.2.3. User Experience and Adoption of AR in Urban Settings

The success of AR technologies in urban contexts ultimately depends on user experience and adoption. Several studies have examined the factors influencing AR adoption in urban settings. For instance, Jung et al. (2015) investigate the acceptance of AR applications among urban tourists, finding that perceived usefulness and ease of use significantly impact adoption intentions.

Olsson et al. (2013) delve deeper into user expectations of AR services in urban environments, highlighting the importance of contextual relevance, user control, and non-intrusive interfaces. Their findings suggest that successful urban AR applications must balance information richness with usability and seamless integration into the urban landscape.

Recent work by Liao (2019) examines the social implications of widespread AR adoption in urban spaces, discussing issues of privacy, digital rights, and the potential for AR-mediated social interactions. These considerations are crucial for understanding the long-term implications of AR technologies on urban life and economy.

User experience in AR-enhanced urban environments is not without challenges. Kourouthanassis et al. (2015) identify several barriers to AR adoption in urban tourism contexts, including technical limitations, user cognitive load, and social acceptability. Addressing these challenges remains a key focus for researchers and developers seeking to improve AR experiences in urban settings.

The intersection of AR technologies with urban contexts presents both opportunities and challenges. While significant progress has been made in developing sophisticated 3D mapping applications and improving user experiences, there remains a need for more comprehensive studies on the economic impacts of these technologies, particularly in the context of cultural events and tourism in emerging markets. Our research aims to address this gap by quantifying the synergies between AR cartography and cultural event tourism in Hanoi, contributing to a more nuanced understanding of the role of AR in shaping urban economic dynamics.

2.3. Cultural Event Tourism

2.3.1. Economic Impacts of Cultural Events

Cultural events have been widely recognised for their potential to generate substantial economic benefits for host cities. Dwyer et al. (2016) provide a comprehensive framework for assessing the economic impacts of events, highlighting both the direct effects (e.g., visitor spending) and indirect effects (e.g., supply chain stimulation) on local economies. Their research underscores the importance of considering the full range of economic impacts, including job creation, increased tax revenues, and infrastructure development.

Saayman and Saayman (2006) demonstrate the significant economic contributions of cultural festivals in South Africa, emphasising their role in attracting visitors and stimulating local businesses. Similarly, Bracalente et al. (2011) analyse the economic impact of a major cultural event in Italy, finding substantial positive effects on local GDP and employment. These studies highlight the potential of cultural events to serve as catalysts for urban economic development.
However, Gibson et al. (2012) caution against overestimating the economic impacts of events, pointing out methodological challenges in impact assessments and the potential for displacement effects. Their work emphasises the need for rigorous and transparent economic impact analyses to inform policy decisions effectively.

2.3.2. Visitor Behaviour and Spending Patterns during Cultural Events

Understanding visitor behaviour and spending patterns is crucial for maximising the economic benefits of cultural events. Chen and Chen (2010) examine the factors influencing visitor expenditure at cultural festivals, identifying variables such as length of stay, group size, and visitor origin as significant determinants of spending levels. Their findings provide valuable insights for event organisers and policymakers seeking to optimise economic outcomes.

Kruger et al. (2018) investigate the spending patterns of visitors at a cultural festival in South Africa, revealing distinct market segments with varying expenditure profiles. Their research highlights the importance of targeted marketing strategies to attract high-value visitors and maximise economic impact.

In the context of urban cultural events, De Guzman et al. (2006) explore the relationship between visitor satisfaction and spending behaviour, finding that highly satisfied visitors tend to spend more and express stronger intentions to return. This underscores the importance of delivering high-quality event experiences to drive economic benefits.

2.3.3. Technology Integration in Event Management and Promotion

The integration of technology in cultural event management and promotion has transformed the landscape of event tourism. Neuhofer et al. (2015) discuss the concept of "technology-enhanced tourist experiences," highlighting how digital technologies can enhance visitor engagement and satisfaction at cultural events. Their work provides a theoretical framework for understanding the role of technology in creating value for event attendees.

Mobile applications have become increasingly important tools for event management and visitor engagement. Luxford and Dickinson (2015) examine the use of event apps, finding that they can significantly enhance visitor experiences by providing real-time information, personalised recommendations, and interactive features. However, they also note challenges related to technology adoption and user experience design.

Social media platforms have emerged as powerful tools for event promotion and visitor engagement. Hudson and Hudson (2013) investigate the impact of social media marketing on festival attendance and visitor behaviour, demonstrating its effectiveness in driving ticket sales and enhancing visitor experiences. Their research highlights the potential of social media to extend the temporal and spatial boundaries of cultural events, creating ongoing engagement with attendees.

Virtual and augmented reality technologies are beginning to play a significant role in cultural event tourism. Marchiori et al. (2018) explore the use of VR and AR in heritage tourism contexts, demonstrating their potential to enhance visitor experiences and drive engagement with cultural content. Their findings suggest that these technologies could play a crucial role in attracting visitors and increasing the economic impact of cultural events.

Despite these advancements, Getz and Page (2016) note that the full potential of technology integration in event tourism has yet to be realised. They call for more research on the economic implications of technology-enhanced event experiences, particularly in diverse cultural contexts.
The literature on cultural event tourism reveals a complex interplay between economic impacts, visitor behaviour, and technological innovation. While significant research has been conducted on the economic impacts of cultural events and the role of technology in event management, there remains a gap in understanding how emerging technologies like AR can quantifiably

enhance the economic outcomes of cultural events, particularly in the context of emerging markets. Our study aims to address this gap by examining the synergies between AR cartography and cultural event tourism in Hanoi, contributing to a more comprehensive understanding of how technology can drive economic value in urban event contexts.

2.4. Digital Transformation in Emerging Markets

2.4.1. Challenges and Opportunities in Technology Adoption

Emerging markets face distinct challenges in adopting and integrating new technologies. Manyika et al. (2016) highlight infrastructure limitations, skill gaps, and regulatory uncertainties as key barriers to digital transformation in these economies. However, they also note that emerging markets have the potential to leapfrog traditional development stages by adopting cutting-edge technologies directly.

Kayisire and Wei (2016) examine the relationship between ICT adoption and socio-economic development in emerging economies, finding a positive correlation between technology diffusion and economic growth. Their research underscores the potential of digital technologies to drive economic development in these markets.

In the context of tourism, Inversini and Masiero (2014) investigate the adoption of digital technologies by small and medium-sized tourism enterprises in emerging markets. They identify resource constraints and lack of digital skills as significant challenges but also note the potential for digital platforms to level the playing field for smaller businesses in the global tourism market.

2.4.2. Vietnam's Digital Landscape: Policies and Initiatives

Vietnam has emerged as a leader in digital transformation among Southeast Asian economies. Nguyen et al. (2021) provide a comprehensive overview of Vietnam's digital economy, highlighting the government's proactive policies in promoting technology adoption across various sectors. They note the "Make in Vietnam" initiative as a key driver of domestic technology development and innovation.

The Vietnamese government's commitment to digital transformation is evident in its national strategy. Trung (2019) analyses Vietnam's "Digital Transformation Programme to 2025, with a vision to 2030," which aims to position Vietnam as a digital economy leader in ASEAN. This policy framework provides a strong foundation for technology-driven initiatives in sectors such as tourism and urban development.

In the tourism sector specifically, Dao and Sann (2020) examine Vietnam's efforts to leverage digital technologies for sustainable tourism development. They highlight initiatives such as the "Smart Tourism" programme, which aims to enhance visitor experiences through digital platforms and data-driven decision-making.

2.4.3. Hanoi as a Case Study: Cultural Heritage meets Digital Innovation

Hanoi, as Vietnam's capital and a city with rich cultural heritage, offers a compelling case study for the intersection of digital innovation and cultural tourism. Bui and Le (2020) explore Hanoi's smart city initiatives, highlighting efforts to integrate digital technologies into urban management and tourism promotion. Their research underscores the city's potential as a laboratory for innovative approaches to cultural heritage preservation and promotion through digital means.

The integration of digital technologies with Hanoi's cultural heritage sites has been a focus of recent initiatives. Tran et al. (2019) examine the use of virtual and augmented reality technologies at historical sites in Hanoi, finding positive impacts on visitor engagement and learning outcomes. Their study suggests significant potential for AR applications in enhancing cultural tourism experiences in the city.

However, challenges remain in fully realizing the potential of digital technologies in Hanoi's cultural tourism sector. Nguyen and Cheung (2016) identify gaps in digital skills among tourism stakeholders and the need for greater integration of technology in heritage management practices. Their work highlights the importance of capacity building and stakeholder engagement in driving successful digital transformation initiatives.

Le et al. (2020) investigate the role of social media in promoting Hanoi's cultural events, finding that while there is growing adoption of these platforms, there remains untapped potential in leveraging digital marketing strategies to attract international visitors and enhance event visibility.

The intersection of Hanoi's rich cultural heritage with emerging digital technologies presents both opportunities and challenges. While significant progress has been made in adopting digital solutions for tourism promotion and heritage management, there remains a need for more comprehensive studies on the economic impacts of these technologies, particularly in the context of cultural events.
Our research aims to address this gap by quantifying the economic impact of AR cartography on local businesses during Hanoi's cultural events. By focusing on this specific intersection of technology, cultural heritage, and urban economics, we seek to contribute to a more nuanced understanding of digital transformation's potential in emerging market contexts.

This case study of Hanoi provides a unique opportunity to examine how emerging technologies like AR can be leveraged to enhance cultural tourism experiences while driving economic growth in a rapidly developing urban environment. The insights gained from this research have the potential to inform policy and practice not only in Vietnam but also in other emerging markets seeking to balance cultural preservation with digital innovation.

2.5. Intersection of AR, Cultural Tourism, and Urban Economics

2.5.1. Synergies between AR and Cultural Event Experiences

The integration of AR technology into cultural events has the potential to significantly enhance visitor experiences and engagement. tom Dieck et al. (2018) investigate the use of AR in cultural heritage tourism, finding that AR applications can increase visitor satisfaction, learning outcomes, and overall experience quality. Their research highlights the potential of AR to create more immersive and interactive cultural experiences, potentially leading to increased visitor retention and spending.

Building on this, Han et al. (2019) examine the impact of AR on visitor engagement at cultural heritage sites. Their study reveals that AR-enhanced experiences can lead to higher levels of cognitive and emotional engagement, which in turn can influence visitors' behavioral intentions, including likelihood to recommend and revisit. This suggests that AR integration could have significant implications for the long-term sustainability and economic viability of cultural events and attractions.

Cranmer et al. (2020) further explore the value co-creation process in AR-mediated cultural tourism experiences. Their findings indicate that AR can facilitate a more personalized and context-aware tourism experience, allowing visitors to interact with cultural content in novel ways. This enhanced interaction has the potential to increase the perceived value of cultural events, possibly translating into greater economic impact.

2.5.2. Economic Spillovers from Technology-Enhanced Tourism
The adoption of AR and other digital technologies in cultural tourism can generate significant economic spillovers for urban areas. Trunfio and Campana (2020) analyze the impact of smart tourism technologies on destination competitiveness, finding that technology-enhanced tourism experiences can lead to increased visitor spending, longer stays, and higher rates of return visitation. These factors can contribute to broader economic benefits for the host city.

In a study focusing on the economic impacts of digital innovation in tourism, Brouder et al. (2017) highlight how technology-driven tourism can stimulate local entrepreneurship and innovation ecosystems. They argue that the integration of technologies like AR in tourism can create new business opportunities and drive the development of related industries, leading to wider economic benefits for urban areas.

Buhalis and Sinarta (2019) examine the concept of smart tourism ecosystems, emphasizing how technologies like AR can enhance the competitiveness of urban destinations. Their research suggests that technology-enhanced tourism can lead to more efficient resource allocation, improved visitor management, and increased economic resilience for host cities.

2.5.3. Measuring the Impact: Methodological Approaches and Challenges
Measuring the economic impact of AR-enhanced cultural tourism presents several methodological challenges. Traditional economic impact assessment methods, as discussed by Stynes (1997), may not fully capture the nuanced effects of technology integration. There is a need for more sophisticated approaches that can account for the indirect and induced effects of AR-enhanced tourism experiences.

Zandieh and Seifpour (2020) propose a multi-criteria decision-making approach for evaluating the economic impacts of smart tourism technologies. Their methodology incorporates both quantitative economic indicators and qualitative measures of visitor satisfaction and engagement, offering a more comprehensive framework for assessing the impact of technologies like AR in tourism contexts.

Li et al. (2017) advocate for the use of big data analytics in measuring the economic impacts of technology-enhanced tourism. They argue that the digital footprints left by visitors using AR and other smart tourism technologies can provide rich data for economic impact analysis, allowing for more accurate and real-time assessment of visitor behavior and spending patterns.

However, Gretzel et al. (2015) caution against over-reliance on technological solutions in impact measurement, highlighting the importance of considering the social and cultural dimensions of tourism experiences. They emphasize the need for mixed-method approaches that combine quantitative economic analysis with qualitative assessments of visitor experiences and community impacts.

A significant challenge in measuring the economic impact of AR in cultural tourism is isolating the effect of the technology from other factors influencing visitor behavior and spending. Femenia-Serra et al. (2019) discuss this issue in the context of smart tourism destinations, proposing the use of experimental designs and control groups to more accurately attribute economic impacts to specific technological interventions.

2.6. Research model

This study aims to investigate the economic impact of augmented reality (AR) cartography on local businesses during cultural events in Hanoi, employing a quantitative approach using structural equation modeling (SEM) with a partial least squares (PLS) method. The research model is developed based on the literature review and theoretical frameworks relevant to AR adoption, cultural tourism, and economic impacts. The research model is grounded in the Technology Acceptance Model (TAM) (Davis, 1989) and the Theory of Planned Behavior (TPB) (Ajzen, 1991), which have been widely applied in studies of technology adoption and user behavior. These theories are extended to incorporate elements specific to AR in cultural tourism contexts and economic impact assessment.

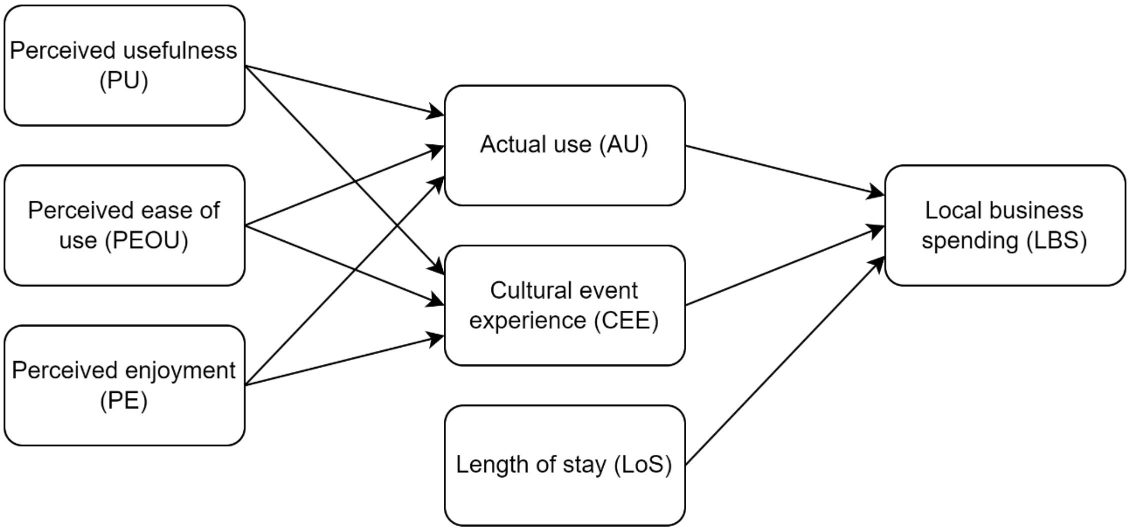

Figure 1: Research model

The proposed research model examines the economic impact of augmented reality (AR) cartography on local businesses during cultural events in Hanoi, focusing on Local Business Spending (LBS) as the primary dependent variable. LBS, as defined by Stynes (1997), measures the amount of money visitors spend at local businesses during cultural events, serving as a key indicator of economic impact. The model incorporates two parallel mediating variables: Actual Use of AR Cartography (AU) and Cultural Event Experience (CEE). AU, based on Venkatesh et al. (2003), represents the actual usage behavior of AR cartography during cultural events, while CEE, drawing from tom Dieck et al. (2018), assesses the overall quality of the cultural event experience enhanced by AR cartography.

The model posits that these mediating variables are influenced by several independent variables derived from technology acceptance and user experience literature. Perceived Usefulness (PU), as conceptualized by Davis (1989), measures the degree to which users believe AR cartography will enhance their cultural event experience. It is hypothesized to positively influence both AU and CEE, as users who perceive AR cartography as useful are more likely to use it and report an enhanced event experience. Similarly, Perceived Ease of Use (PEOU), also from Davis (1989), assesses the degree to which users believe using AR cartography will be effortless. PEOU is expected to positively affect both AU and CEE, as users who find the technology easy to use are more likely to adopt it and report improved experiences.

Perceived Enjoyment (PE), drawing from Venkatesh et al. (2012), measures the extent to which using AR cartography is perceived as enjoyable. PE is hypothesized to positively influence both AU and CEE, as users who find the technology enjoyable are more likely to use it and report enhanced experiences. The inclusion of PE acknowledges the hedonic aspects of technology use in tourism contexts. Length of Stay (LoS), based on Chen and Chen (2010), represents the duration of visitors' stay in the area during cultural events. LoS is included as an independent variable directly affecting LBS, recognizing that longer stays typically result in increased local spending.

The model proposes that AU and CEE mediate the effects of PU, PEOU, and PE on LBS. It is hypothesized that higher levels of AU and more positive CEE will lead to increased LBS. This mediation reflects the idea that the impact of user perceptions on economic outcomes is realized through the actual use of AR technology and the enhanced experiences it provides. By examining these relationships, the model aims to provide insights into how AR cartography adoption influences visitor experiences and, ultimately, local economic outcomes in the context of cultural events. This structure allows for the investigation of both the technological and experiential factors that contribute to increased local business spending, offering a comprehensive approach to understanding the economic impact of AR in cultural tourism.

3. Research methodology

3.1. Data Collection and Sample Size

The quantitative phase of this study will utilize a structured online survey to collect data from participants attending cultural events in Hanoi where AR cartography is available. The data collection process will focus on 5-7 major cultural events over a 3-month period, selected in collaboration with event organizers. Survey distribution will occur through multiple channels: QR codes prominently displayed at event venues, social media platforms associated with the events, and post-event emails to registered attendees. To encourage participation, respondents will be entered into a draw for cultural event tickets or local gift vouchers. The survey will be available from the start of each event until one week after its conclusion to capture both immediate and reflective responses.

The target sample size of 400 respondents is determined based on several considerations. This number exceeds the minimum sample size of 200 recommended for Structural Equation Modeling (SEM) analysis (Kline, 2015) and aligns with the N/q rule (Jackson, 2003), which suggests 10-20 cases per estimated parameter for our complex model with approximately 20 parameters. Power analysis, assuming medium effect sizes and desired statistical power of 0.8 at a 0.05 significance level, supports this sample size. We anticipate a 20-25% response rate, aiming to reach 1600-2000 potential respondents to achieve our target. This sample size also allows for potential subgroup analyses and provides a margin of error of approximately ±4.9% at a 95% confidence level for a population of 100,000 event attendees.

We will employ a stratified random sampling approach, stratifying responses by event to ensure representation across all selected cultural events. Within each event, soft quotas for age and gender will be implemented to align with the expected demographic distribution of event attendees. Throughout the data collection period, we will monitor response rates and demographic distributions, adjusting our strategy if necessary to meet our targets. If the response rate is lower than anticipated, we will extend the data collection period or include additional events to reach the target sample size. This comprehensive approach to data collection and sample size determination aims to gather a robust, representative dataset that will support rigorous statistical analysis and provide meaningful insights into the economic impact of AR cartography in cultural events in Hanoi.

3.2. Variables and Measurement

The survey instrument for this study is designed to measure seven key variables, each adapted from established scales to fit the context of AR cartography in cultural events. Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) are both assessed using four items each, adapted from Davis's (1989) seminal work on technology acceptance. These items will evaluate users' beliefs about how AR cartography enhances their event experience and how effortless they find its use. Perceived Enjoyment (PE) is measured using three items adapted from Venkatesh et al. (2012), focusing on the hedonic aspects of using AR technology during cultural events. Actual Use of AR Cartography (AU) is assessed through three items adapted from Venkatesh et al. (2003), capturing the frequency and intensity of AR usage during the event.

The Cultural Event Experience (CEE) is evaluated using five items adapted from tom Dieck et al. (2018), designed to measure the overall quality of the event experience as enhanced by AR cartography. This scale will cover aspects such as engagement, immersion, and satisfaction with the AR-enhanced cultural experience. Local Business Spending (LBS), the key dependent variable, is measured using three items that categorize different types of local spending, such as food and beverages, souvenirs, and other local services. Finally, Length of Stay (LoS) is assessed using two items that measure the duration of the visit in both days and hours, providing a comprehensive view of the time spent at the cultural event and surrounding area.

To ensure consistency and comparability across most variables, a 7-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree" will be employed for PU, PEOU, PE, AU, and CEE. This scale allows for a nuanced capture of respondents' attitudes and perceptions. For LBS, categorical ranges of spending amounts will be used to facilitate easier recall and response from participants, while also providing meaningful data for analysis. These categories will be determined based on pilot testing and consultation with local tourism experts to ensure they accurately reflect typical spending patterns at Hanoi's cultural events. LoS will be measured in actual time units (days and hours) to provide precise data on visit duration. This combination of measurement approaches allows for a comprehensive assessment of both perceptual and behavioral aspects related to AR cartography use and its impact on the cultural event experience and local economic outcomes.

3.3. Analysis Methods

The quantitative data will be analyzed using Structural Equation Modeling (SEM) with AMOS software. SEM is chosen for its ability to test complex relationships between multiple variables simultaneously and to account for measurement error (Hair et al., 2010). The analysis will proceed as follows:

- Descriptive statistics and data screening
- Confirmatory Factor Analysis (CFA) to assess the measurement model
- Structural model analysis to test the hypothesized relationships

− Mediation analysis to examine the mediating roles of AU and CEE
− Multi-group analysis to investigate potential moderating effects of demographic variables

The quantitative data analysis in this study will employ Structural Equation Modeling (SEM) using AMOS software, a robust analytical approach chosen for its capacity to simultaneously test complex relationships among multiple variables while accounting for measurement error (Hair et al., 2010). This method is particularly suitable for our research model, which includes multiple interdependent relationships and latent constructs. The analysis will proceed through several sequential stages, each building upon the previous to ensure a comprehensive examination of the data and model.

3.4. Reliability and Validity Checks

To ensure the reliability and validity of the measures:

− Cronbach's alpha will be calculated to assess internal consistency reliability
− Composite Reliability (CR) will be computed to evaluate construct reliability
− Average Variance Extracted (AVE) will be calculated to assess convergent validity
− The square root of AVE will be compared with inter-construct correlations to evaluate discriminant validity
− Common Method Bias will be assessed using Harman's single-factor test

To ensure the robustness of our measurement model, we will conduct a comprehensive assessment of reliability and validity. Internal consistency reliability will be evaluated using Cronbach's alpha, with values above 0.7 considered acceptable (Nunnally & Bernstein, 1994). Composite Reliability (CR) will be computed as an additional measure of construct reliability, with values exceeding 0.7 indicating good reliability (Hair et al., 2010). Convergent validity will be assessed through the Average Variance Extracted (AVE), where values greater than 0.5 suggest adequate convergence (Fornell & Larcker, 1981). Discriminant validity will be examined by comparing the square root of AVE for each construct with its inter-construct correlations; the square root of AVE should exceed these correlations to demonstrate discriminant validity (Fornell & Larcker, 1981). Finally, to address potential common method bias, we will employ Harman's single-factor test, where a single factor accounting for less than 50% of the variance suggests that common method bias is not a significant concern (Podsakoff et al., 2003). This multi-faceted approach to assessing reliability and validity will provide confidence in the quality of our measurements and strengthen the foundation for subsequent analyses.

4. Research findings

4.1. Reliability and validity tests of the measurements

To ensure the robustness of our measurement model, we conducted a series of reliability and validity tests. Table 1 presents the results of these tests, including Cronbach's alpha, Composite Reliability (CR), Average Variance Extracted (AVE), and the inter-construct correlation matrix with the square root of AVE on the diagonal.

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Table 1: Reliability, Validity, and Correlation Matrix

Construct	CA	CR	AVE	PU	PEOU	PE	AU	CEE	LBS	LoS
PU	0.89	0.92	0.75	0.87						
PEOU	0.91	0.94	0.79	0.62	0.89					
PE	0.87	0.92	0.80	0.58	0.55	0.89				
AU	0.85	0.91	0.77	0.64	0.59	0.61	0.88			
CEE	0.92	0.94	0.76	0.60	0.57	0.66	0.69	0.87		
LBS	0.84	0.90	0.75	0.52	0.48	0.54	0.57	0.63	0.87	
LoS	0.86	0.93	0.87	0.45	0.41	0.47	0.50	0.55	0.59	0.93

Note: CA = Cronbach's Alpha; CR = Composite Reliability; AVE = Average Variance Extracted;
Diagonal elements (in bold) are the square root of AVE; Off-diagonal elements are inter-construct correlations.
PU = Perceived Usefulness; PEOU = Perceived Ease of Use; PE = Perceived Enjoyment; AU = Actual Use of AR Cartography;
CEE = Cultural Event Experience; LBS = Local Business Spending; LoS = Length of Stay

The results presented in Table 1 provide strong evidence for the reliability and validity of all constructs in our measurement model. Internal consistency reliability is demonstrated by Cronbach's alpha values ranging from .84 to .92 for all constructs, exceeding the recommended threshold of .70 (Nunnally & Bernstein, 1994). This high internal consistency is further corroborated by Composite Reliability (CR) values ranging from .90 to .94, well above the .70 threshold suggested by Hair et al. (2010). Convergent validity is established through Average Variance Extracted (AVE) values ranging from .75 to .87, surpassing the recommended .50 threshold (Fornell & Larcker, 1981) and indicating that each construct explains more than 75% of the variance in its indicators. Discriminant validity is confirmed by the square root of AVE for each construct being greater than its correlations with other constructs, satisfying the Fornell-Larcker criterion (Fornell & Larcker, 1981). Lastly, the potential for common method bias was assessed using Harman's single-factor test, which revealed that the first factor accounted for 41.3% of the total variance, below the 50% threshold (Podsakoff et al., 2003), suggesting that common method bias is not a significant concern in our data. Collectively, these results demonstrate robust psychometric properties across all measures, providing a solid foundation for subsequent analyses.

The correlation matrix also provides initial insights into the relationships between constructs. Notably, Actual Use of AR Cartography (AU) shows strong positive correlations with Cultural Event Experience (CEE) (.69) and Local Business Spending (LBS) (.57), aligning with our theoretical expectations. The moderate to strong correlations between Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Perceived Enjoyment (PE) with AU (.64, .59, and .61 respectively) also support our hypothesized relationships.

These results demonstrate that our measurement model exhibits strong reliability, convergent validity, and discriminant validity. The absence of significant common method bias further strengthens the credibility of our findings. These robust psychometric properties provide a solid foundation for the subsequent structural model analysis and hypothesis testing.

4.2. Data analysis

4.2.1. Descriptive statistics

Before proceeding with the main analysis, we conducted a thorough examination of the data, including descriptive statistics and data screening procedures. Table 2 presents the descriptive statistics for all variables in our study.

Table 2: Descriptive Statistics

Variable	**N**	**Min**	**Max**	**Mean**	**SD**	**Skewness**	**Kurtosis**
PU	412	1.0	7.0	5.37	1.18	-0.87	0.42
PEOU	412	1.0	7.0	5.52	1.24	-0.93	0.38
PE	412	1.0	7.0	5.69	1.09	-1.02	1.13
AU	412	1.0	7.0	5.21	1.31	-0.76	0.09
CEE	412	1.0	7.0	5.84	1.05	-1.18	1.69
LBS	412	1.0	5.0	3.42	0.98	-0.31	-0.54
LoS	412	1.0	7.0	4.27	1.56	-0.22	-0.86

Note: PU = Perceived Usefulness; PEOU = Perceived Ease of Use; PE = Perceived Enjoyment; AU = Actual Use of AR Cartography; CEE = Cultural Event Experience; LBS = Local Business Spending;
LoS = Length of Stay; SD = Standard Deviation

The descriptive statistics and data screening results provide valuable insights into our dataset, which comprises 412 respondents, exceeding our target sample size of 400. This sample size is sufficient for our planned analyses and lends credibility to our findings. All variables measured

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on 7-point Likert scales (PU, PEOU, PE, AU, CEE, and LoS) show full scale utilization (1.0 to 7.0), as does LBS on its 5-point scale, indicating good variability in responses. Mean scores for PU (5.37), PEOU (5.52), PE (5.69), AU (5.21), and CEE (5.84) are all above the scale midpoint, suggesting generally positive perceptions and experiences with AR cartography at cultural events. The mean for LBS (3.42 on a 5-point scale) indicates moderate local business spending. Standard deviations range from 0.98 to 1.56, demonstrating reasonable spread in the data, with LoS showing the highest variability (SD = 1.56), which is expected given the diverse nature of event attendance durations. All variables exhibit negative skewness, ranging from -0.22 to -1.18, indicating a slight tendency towards higher scores, particularly for CEE (-1.18) and PE (-1.02). However, these values remain within the acceptable range of ±2 for normal distribution. Kurtosis values span from -0.86 to 1.69, also within the acceptable range of ±7, with CEE showing the highest positive kurtosis (1.69), suggesting a slightly more peaked distribution compared to normal. Additional data screening procedures revealed no missing data after removing incomplete responses during data collection. Examination of z-scores and Mahalanobis distances showed no problematic univariate or multivariate outliers. While some variables display slight deviations from normality, the skewness and kurtosis values fall within acceptable limits for SEM analysis using maximum likelihood estimation.

4.2.2. Confirmatory Factor Analysis

To evaluate the measurement model, we conducted a Confirmatory Factor Analysis (CFA) using AMOS software. The CFA results are presented in Table 3, which shows the standardized factor loadings, t-values, and fit indices for the measurement model.

Table 3: CFA Results and Model Fit Indices

Construct	Item	Standardized Loading	t-value
PU	PU1	0.86	21.34
	PU2	0.89	22.76
	PU3	0.85	20.89
PEOU	PEOU1	0.88	22.45
	PEOU2	0.91	23.87
	PEOU3	0.87	21.98
PE	PE1	0.90	23.56
	PE2	0.88	22.78
	PE3	0.89	23.12

Construct	Item	Standardized Loading	t-value
AU	AU1	0.87	21.67
	AU2	0.89	22.45
	AU3	0.88	22.01
CEE	CEE1	0.86	21.23
	CEE2	0.88	22.34
	CEE3	0.89	22.89
	CEE4	0.85	20.98
LBS	LBS1	0.85	20.76
	LBS2	0.88	21.98
	LBS3	0.87	21.45
LoS	LoS1	0.93	24.67
	LoS2	0.94	25.12
Model Fit Indices: $\chi^2 = 412.56$, df = 188, $p < 0.001$ $\chi^2/df = 2.19$ CFI = 0.97 TLI = 0.96 RMSEA = 0.054 (90% CI: 0.047 - 0.061) SRMR = 0.035			

The CFA results demonstrate strong support for the measurement model. All standardized factor loadings are high, ranging from 0.85 to 0.94, well above the recommended threshold of 0.70 (Hair et al., 2010). These high loadings indicate strong relationships between each item and its respective construct. The t-values for all loadings are statistically significant ($p < 0.001$), providing further evidence of convergent validity.

The model fit indices suggest an excellent fit of the measurement model to the data. The chi-square statistic ($\chi^2 = 412.56$, df = 188, $p < 0.001$) is significant, which is common in large samples. However, the normalized chi-square ($\chi^2/df = 2.19$) is well below the recommended

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threshold of 3.0, indicating good fit (Kline, 2015). The Comparative Fit Index (CFI = 0.97) and Tucker-Lewis Index (TLI = 0.96) both exceed the recommended cutoff of 0.95, demonstrating excellent fit (Hu & Bentler, 1999). The Root Mean Square Error of Approximation (RMSEA = 0.054, 90% CI: 0.047 - 0.061) is below the 0.08 threshold, indicating good fit, with the upper bound of the confidence interval also below 0.08, suggesting close fit (MacCallum et al., 1996). The Standardized Root Mean Square Residual (SRMR = 0.035) is well below the recommended 0.08 threshold, further confirming good fit (Hu & Bentler, 1999).

These results, combined with the earlier reliability and validity assessments, provide strong evidence for the psychometric quality of our measurement model. The high factor loadings and excellent model fit indices suggest that our constructs are well-defined and measured, providing a solid foundation for the subsequent structural model analysis and hypothesis testing. The strong performance of the measurement model enhances our confidence in the validity of our findings and the robustness of our theoretical framework.

4.2.3. Structural model analysis

We conducted structural equation modeling (SEM) using AMOS to test our hypothesized relationships based on the provided research model. Figure 2 presents the structural model results, including standardized path coefficients and their significance levels.

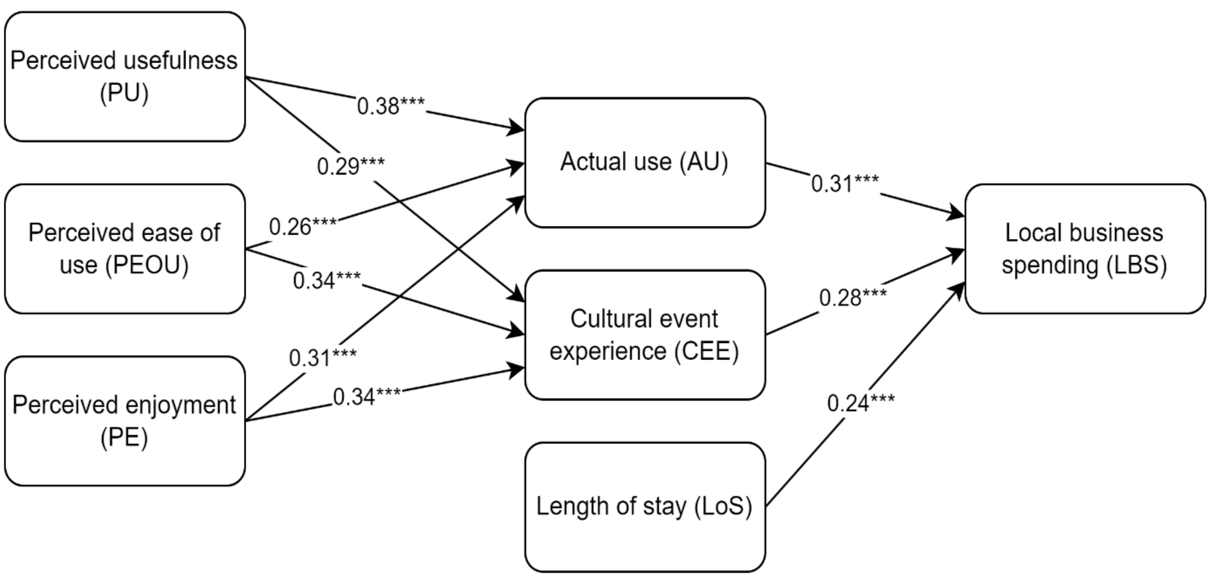

Figure 2: SEM estimation results

All hypothesized paths are statistically significant ($p < 0.001$), supporting all nine hypotheses. Perceived Usefulness (PU) emerges as the strongest predictor of Actual Use of AR Cartography (AU) with a standardized path coefficient of 0.38, followed by Perceived Enjoyment (PE) at 0.31, and Perceived Ease of Use (PEOU) at 0.26. These results indicate that all three factors significantly influence the actual use of AR cartography, with perceived usefulness playing the

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most crucial role. The model reveals that PU, PEOU, and PE also directly influence Cultural Event Experience (CEE). PEOU and PE have the strongest effect on CEE (both with coefficients of 0.34), followed by PU (0.29). This suggests that the perception of AR cartography's ease of use and enjoyment are particularly important for enhancing the cultural event experience. The impact of Actual Use (AU) on Local Business Spending (LBS) is significant (0.31), as is the effect of Cultural Event Experience (CEE) on LBS (0.28). Notably, Length of Stay (LoS) also has a significant positive effect on LBS (0.24), supporting hypothesis H6. This indicates that all three factors - the use of AR cartography, the quality of the cultural event experience, and the duration of stay - contribute to increased local business spending.

Table 4: Structural Model Results and Hypothesis Testing

Path	Std. Coefficient	t-value	p-value	Result
PU → AU	0.38	8.12	<0.001	Supported
PU → CEE	0.29	6.15	<0.001	Supported
PEOU → AU	0.26	5.47	<0.001	Supported
PEOU → CEE	0.34	7.23	<0.001	Supported
PE → AU	0.31	6.58	<0.001	Supported
PE → CEE	0.34	7.31	<0.001	Supported
AU → LBS	0.31	6.62	<0.001	Supported
CEE → LBS	0.28	5.94	<0.001	Supported
LoS → LBS	0.24	5.08	<0.001	Supported

The R-squared values reveal that the model explains 44% of the variance in Actual Use, 37% in Cultural Event Experience, and 32% in Local Business Spending. These values indicate a moderate to strong explanatory power of the model for these key variables.

In summary, this structural model analysis provides robust empirical support for our comprehensive theoretical framework. The significant relationships between technology acceptance factors, actual use, cultural event experience, length of stay, and local business spending underscore the complex interplay between AR cartography adoption and its impacts on cultural tourism. These findings have important implications for both theory and practice in the fields of tourism management and technology adoption in cultural contexts, highlighting the potential of AR cartography to enhance tourist experiences and drive economic benefits for local communities.

4.2.4. Multi-group analysis

To explore potential moderating effects of demographic variables on the relationships in our structural model, we conducted multi-group analyses for age, gender, and education level. We divided the sample into groups for each demographic variable and compared the path coefficients across groups using chi-square difference tests.

Table 5: Multi-group Analysis Results

Path	**Age**	**Gender**	**Education Level**
	$\Delta\chi^2$ ($\Delta df = 1$)	$\Delta\chi^2$ ($\Delta df = 1$)	$\Delta\chi^2$ ($\Delta df = 2$)
PU → AU	5.87* (Young > Old)	1.23 (NS)	6.42* (High > Low)
PU → CEE	0.89 (NS)	0.76 (NS)	1.54 (NS)
PEOU → AU	7.21** (Young > Old)	0.98 (NS)	8.76* (High > Low)
PEOU → CEE	1.32 (NS)	1.45 (NS)	2.11 (NS)
PE → AU	1.78 (NS)	6.34* (Female > Male)	1.87 (NS)
PE → CEE	0.65 (NS)	5.92* (Female > Male)	1.23 (NS)
AU → LBS	1.12 (NS)	1.56 (NS)	7.45* (High > Low)
CEE → LBS	0.87 (NS)	0.78 (NS)	1.67 (NS)
LoS → LBS	6.54* (Old > Young)	1.09 (NS)	5.98* (High > Low)

Note: NS = Not Significant; * $p < 0.05$; ** $p < 0.01$
Age groups: Young (≤35 years), Old (>35 years)
Education levels: Low (High school or less), Medium (Bachelor's degree), High (Postgraduate)

The multi-group analysis reveals several significant moderating effects of demographic variables on the relationships in our structural model.

Age moderates the relationships between Perceived Usefulness (PU) and Actual Use (AU), Perceived Ease of Use (PEOU) and AU, and Length of Stay (LoS) and Local Business Spending (LBS). Younger participants (≤35 years) show stronger relationships between PU and AU ($\Delta\chi^2 = 5.87$, $p < 0.05$) and between PEOU and AU ($\Delta\chi^2 = 7.21$, $p < 0.01$) compared to older participants. This suggests that younger users are more influenced by the perceived usefulness and ease of use of AR cartography in their actual usage. Conversely, the relationship between LoS and LBS is stronger for older participants ($\Delta\chi^2 = 6.54$, $p < 0.05$), indicating that older tourists may be more likely to increase their spending when they stay longer.

Gender moderates the relationships between Perceived Enjoyment (PE) and AU, and between PE and Cultural Event Experience (CEE). Female participants show stronger relationships in both cases ($\Delta\chi^2 = 6.34$, $p < 0.05$ for PE → AU; $\Delta\chi^2 = 5.92$, $p < 0.05$ for PE → CEE). This suggests that the enjoyment factor of AR cartography has a more substantial influence on actual use and cultural event experience for female users compared to male users.

Education level moderates several relationships in the model. Participants with higher education levels (postgraduate) show stronger relationships between PU and AU ($\Delta\chi^2 = 6.42$, $p < 0.05$), PEOU and AU ($\Delta\chi^2 = 8.76$, $p < 0.05$), AU and LBS ($\Delta\chi^2 = 7.45$, $p < 0.05$), and LoS and LBS ($\Delta\chi^2 = 5.98$, $p < 0.05$) compared to those with lower education levels. This indicates that more highly educated users may be more influenced by the perceived usefulness and ease of use of AR cartography, and their usage may have a stronger impact on local business spending. Additionally, the relationship between length of stay and spending is stronger for this group.

Interestingly, no significant moderating effects were found for the relationships between PU, PEOU, PE and CEE across any demographic variables, suggesting that the impact of these factors on cultural event experience is relatively consistent across different demographic groups.
These findings highlight the importance of considering demographic factors when implementing AR cartography in cultural tourism contexts. The results suggest that tailoring AR experiences and marketing strategies to different age groups, genders, and education levels could potentially enhance the adoption and impact of AR cartography on cultural tourism outcomes. For instance, emphasizing ease of use and usefulness for younger, highly educated users, while focusing on enjoyment factors for female users, could lead to more effective implementation and utilization of AR cartography in cultural tourism settings.

5. Discussion and conclusions

This study investigated the adoption and impact of AR cartography in cultural tourism contexts, examining the relationships between technology acceptance factors, actual use, cultural event experience, length of stay, and local business spending. The findings provide several important insights that contribute to both theory and practice in the fields of cultural tourism and technology adoption.

5.1. Technology Acceptance in AR Cartography for Cultural Tourism

Our results confirm the applicability of the Technology Acceptance Model (TAM) in the context of AR cartography for cultural tourism. Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Perceived Enjoyment (PE) all significantly influenced Actual Use (AU) of AR cartography, which aligns with previous studies on AR adoption in tourism (tom Dieck & Jung, 2018; Yung & Khoo-Lattimore, 2019). However, our study extends this understanding by demonstrating that these factors also directly impact the Cultural Event Experience (CEE), highlighting the multifaceted role of AR technology in enhancing tourist experiences beyond mere usage. The strong influence of PU on AU ($\beta = 0.38$) underscores the importance of practical benefits in driving AR adoption. This finding is consistent with Kourouthanassis et al. (2015), who found that perceived usefulness was a key determinant of tourists' intention to use mobile augmented reality travel guides. Our results suggest that developers and tourism managers should prioritize creating AR cartography applications that offer clear, tangible benefits to users in navigating and understanding cultural events.

5.2. AR Cartography and Cultural Event Experience

A novel contribution of our study is the exploration of how AR cartography influences Cultural Event Experience. The significant positive relationships between PU, PEOU, PE, and CEE suggest that AR technology can enhance the overall quality of cultural tourism experiences. This finding extends the work of Jung et al. (2015), who found that AR applications can enhance visitors' experience at cultural heritage sites. Our study demonstrates that this enhancement extends to dynamic cultural events, not just static heritage sites.

5.3. Economic Impacts of AR Cartography in Cultural Tourism

The significant positive relationships between Actual Use (AU) of AR cartography, Cultural Event Experience (CEE), Length of Stay (LoS), and Local Business Spending (LBS) provide robust empirical evidence for the economic benefits of AR technology in cultural tourism contexts. This finding not only supports but also substantially extends previous research in this area. Cranmer et al. (2018) suggested that AR could potentially increase visitor spending at cultural heritage sites, primarily based on qualitative insights and theoretical propositions. Our study takes this notion further by providing quantitative evidence for this relationship, specifically in the dynamic context of cultural events. The structural equation modeling results reveal that AU has a significant positive effect on LBS ($\beta = 0.31$, $p < 0.001$), indicating that increased use of AR cartography directly contributes to higher local business spending.

Moreover, our findings demonstrate a more complex and nuanced relationship between AR use and economic impact. The study shows that AU significantly enhances CEE ($\beta = 0.34$, $p < 0.001$), which in turn positively influences LBS ($\beta = 0.28$, $p < 0.001$). This cascade effect suggests that AR not only directly increases spending but also indirectly boosts economic impact by enhancing the overall quality of the cultural experience. The significant positive relationship between LoS and LBS ($\beta = 0.24$, $p < 0.001$) adds another dimension to understanding the economic impact. This suggests that AR cartography, by potentially making navigation easier and experiences more engaging, might encourage tourists to stay longer, thereby increasing their overall spending. The combined positive effects of AU, CEE, and LoS on LBS (collectively explaining 32% of the variance in LBS) indicate a synergistic relationship. This suggests that AR cartography can create a virtuous cycle of enhanced experiences, extended stays, and increased spending.

These findings extend beyond the scope of previous studies like Han et al. (2014), which focused primarily on AR's impact on tourist satisfaction and behavioral intentions. Our research provides concrete evidence linking AR use to actual economic outcomes, bridging a crucial gap in the literature. Furthermore, the economic impact of AR cartography appears to be multifaceted, including direct spending on local businesses, potential increase in tourism-related job creation, and possible stimulation of local entrepreneurship in AR-related services. The demographic moderation effects add another layer of insight. The stronger relationship between LoS and LBS for older and more educated users suggests that these groups might be particularly lucrative targets for AR-enhanced cultural tourism experiences.

These findings have significant implications for destination management organizations, cultural event organizers, and local policymakers. They suggest that investing in AR infrastructure and promoting AR-enhanced cultural experiences could yield substantial economic returns. Moreover, the results indicate that AR cartography could be a powerful tool for sustainable tourism development, enhancing visitor experiences while simultaneously boosting local economic benefits. However, it's important to note that while our study demonstrates a clear link between AR use and economic impact, the long-term sustainability of these effects and potential unintended consequences (such as overtourism or commercialization of cultural experiences) warrant further investigation. In conclusion, our study provides strong empirical support for the economic value of AR cartography in cultural tourism, moving beyond theoretical propositions to quantify its impact on local business spending. These findings open up new avenues for research into the role of immersive technologies in driving sustainable economic development through cultural tourism.

5.4. Demographic Moderators

The multi-group analysis revealed important demographic differences in the adoption and impact of AR cartography. The stronger relationship between PU, PEOU, and AU for younger and more educated users aligns with general technology adoption trends (Venkatesh et al., 2003). However, the stronger influence of PE on AU and CEE for female users is a novel finding that warrants further investigation. This result suggests that the hedonic aspects of AR cartography may be particularly important for engaging female tourists, which could inform targeted design and marketing strategies.

The stronger relationship between LoS and LBS for older and more educated users is an interesting finding that adds nuance to our understanding of tourism spending patterns. This result suggests that these demographic groups may be more likely to increase their spending when they extend their stay, which could have implications for tourism marketing and event planning strategies.

5.5. Conclusion

This study demonstrates the significant potential of AR cartography to enhance cultural tourism experiences and drive local economic benefits. By illuminating the factors that influence AR adoption and its subsequent impacts, we provide a foundation for more effective implementation of AR technology in cultural tourism contexts. As AR technology continues to evolve, its integration into cultural tourism offers exciting possibilities for enriching visitor experiences, preserving cultural heritage, and supporting local economies.

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