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Enhancing Sustainable Cultural Tourism through Augmented Reality Smart Guide Systems: The Roles of Service Quality and User Perception

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ABSTRACT

Cultural heritage sites that adopt digital innovation increasingly implement Augmented Reality Smart Tour Guide Systems (AR-STGS) to enrich site-specific visitor engagement by fostering interactive and immersive learning experiences, thereby enhancing the comprehension of historical and cultural narratives. This study proposes and empirically tests a comprehensive model linking perceived service quality, user perceptions, tourist satisfaction, and the overall tourist experience in AR-enabled heritage tourism, grounded in the SERVQUAL framework and the Technology Acceptance Model (TAM). Travelers aged 18–55 who utilized AR-STGS to tour the Palace Museum, Terracotta Army Museum, Liangzhu Ancient City, and Summer Palace provided 658 valid responses. Service quality is highly affected by responsiveness, assurance, and empathy. Utility and simplicity strongly predict user perceptions and experiences, thereby supporting the TAM.

Keywords: Augmented reality smart tour guide systems, service quality, user perception, sustainable cultural tourism, tourist experience

1. INTRODUCTION

AR-STGS significantly transforms the understanding of historical and urban self-guided tours. These technologies provide customers with an immersive, autonomous experience through AR overlays, interactive maps, adaptive route suggestions, and voice-activated narrations, rather than static panels, pamphlets, or structured tours. AR-STGS enables visitors to explore historical reconstructions, access multilingual content, and receive personalized insights tailored to their choices or location within museums, archaeological sites, and culturally significant landscapes. Digital literacy, cultural norms, and service expectations affect subjective judgments about service excellence within the same technology environment. Through functional assessment and emotive and cognitive filtering, service quality impacts visitor experience [1]. Understanding human-technology interaction in complicated cultural contexts is necessary to implement AR-STGS in smart tourism ecosystems. System features, user perceptions, expectations, desires, and digital tool use shape tourist experiences. AR-STGS that combine technology, service, and customer expectations can change historical and urban tourism.

Positioned as a pivotal interface within smart tourism infrastructures, AR-STGS substantially contributes to shaping user perception, exerts a significant influence on tourist satisfaction, and guides downstream behavioral responses. Prior studies suggest that users expect enhanced experience and creativity from augmented reality applications [2].

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Existing research predominantly centers on the functional design and technical performance of AR-based systems, with limited attention to how perceived service quality and user perception collectively mediate affective responses and perceived value across the tourist journey. Motivated by the absence of an integrated perspective in existing literature, this study integrates the SERVQUAL service quality framework with the TAM to develop a comprehensive analytical model that elucidates the perceptual and experiential mechanisms underlying tourists' interactions with AR-STGS. Accordingly, this research is structured around the following key questions of inquiry:

RQ1. How do service quality and user perception associated with smart tour guide systems influence tourist satisfaction?

RQ2. Does tourist satisfaction mediate the relationship between service quality, user perception, and tourist experience?

RQ3. Which dimensions of service quality and user perception have the most significant impact on tourist satisfaction and overall experience?

To explore these questions, a four-stage structural model—Service Quality → User Perception → Tourist Satisfaction → Tourist Experience—is proposed. Empirical data were collected through questionnaire surveys conducted in a real-world smart tourism destination, focusing on user interactions with AR-STGS. The model is validated using Structural Equation Modeling (SEM) to ensure robust analysis and interpretation. This research aims to uncover the underlying mechanisms through which AR-STGS enhances the tourist experience, thereby contributing to the convergence of service management theory and tourism technology research.

2. THEORETICAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

2.1 SERVQUAL Model

Parasuraman, Zeithaml, and Berry's SERVQUAL methodology, developed in the late 1980s, remains a valuable tool for assessing service quality across various disciplines. The quantitative and holistic picture of service quality makes it more meaningful. Service quality is measured by provider performance against customer expectations. The "service gaps" may affect customer satisfaction, loyalty, and perceptions. The methodology identified five service quality dimensions: Tangibles, Reliability, Responsiveness, Assurance, and Empathy, following repeated revision [3]. Each dimension offers a unique yet interrelated perspective on the service encounter, enabling users to understand the quality of the service.

2.2 Technology Acceptance Model (TAM)

The TAM, as proposed by Fred Davis in 1986, explains how users adopt new technology, a popular model in information systems research, particularly for cognitively driven, voluntary technology adoption. The TAM says perceived usefulness (PU) and perceived ease of use (PEOU) influence consumers' attitudes, intentions, and usage behavior [4]. AR-STGS helps passengers explore, provide information, arrange paths, and reduce confusion in unexpected situations. Accurate historical narratives, context-specific content overlays, and real-time navigation signals make AR-STGS more appealing to travelers. PEOU assesses system usability. This encompasses intuitive design, ease of learning, device accessibility, and a few technical issues. Tourists prefer AR-STGS with a clear interface, responsiveness, voice teaching, multilingual support, and learning method support. When users perceive technology as simple and useful, adoption resistance is lessened.

2.3 Research Model and Hypotheses

Building on the preceding theoretical background, this study proposes a composite structural framework that synthesizes the SERVQUAL model and TAM to trace the cognitive and perceptual mechanisms influencing tourist satisfaction and experience in AR-STGS contexts (as illustrated in Figure 1). The five dimensions of SERVQUAL—tangibles, reliability, responsiveness, assurance, and empathy—are theorized as building blocks that affect how tourists judge service quality. At the same time, user perception is guided by the constructs of the TAM, specifically perceived ease of use and perceived usefulness, which are the primary predictors of technology acceptance in augmented reality–enhanced tourism settings. The model enables the conceptualization of a synergistic contribution of service attributes and technological perception to user experience in smart tourism ecosystems when these

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conceptual lenses are integrated.

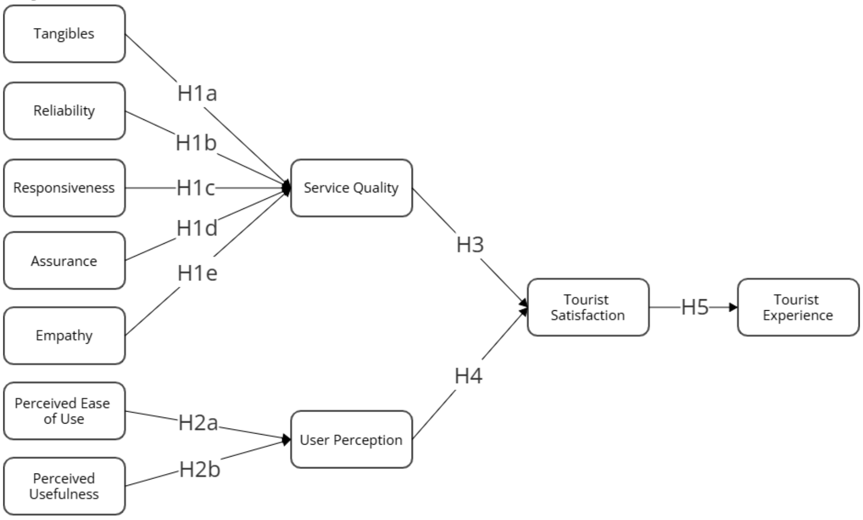

Figure 1. Research model.

Empirical evidence in the domain of digital tourism indicates that tangibility often functions as a gateway to higher levels of perceived trust and service value, particularly in experiences mediated by advanced technologies. Responsiveness—the extent to which the system delivers timely support and reacts effectively to user demands—facilitates positive user interaction and enhances perceived ease and comfort of use [5]. Moreover, assurance, encompassing data security and the perceived professionalism of service delivery, along with empathy, reflected in personalized responses and affective support, have emerged as vital components shaping users' cognitive evaluations of service quality [6]. Building on the aforementioned foundation, the study formulates the following hypotheses:

H1a: The tangibility of AR-STGS positively influences users' perceived overall service quality.

H1b: The reliability of AR-STGS positively influences users' perceived overall service quality.

H1c: The responsiveness of AR-STGS positively influences users' perceived overall service quality.

H1d: The assurance provided by AR-STGS positively influences users' perceived overall service quality.

H1e: The empathy embedded in AR-STGS positively influences users' perceived overall service quality.

Beyond service quality, user perception formed during interaction with the system plays a critical role in shaping tourist satisfaction. According to the Technology Acceptance Model (TAM), Perceived Ease of Use and Perceived Usefulness are key antecedents of user acceptance and satisfaction [7]. Gao and Pan found that users' satisfaction improves significantly when tour guide systems facilitate itinerary planning and enhance cultural understanding [8]. Furthermore, a user-friendly interface and intuitive interaction design increase engagement and positively influence users' perceptions of system usefulness, which in turn drives higher satisfaction levels. Based on the conceptual model, we advance the following testable assumptions:

H2a: Tourists' Perceived Ease of Use of AR-STGS positively influences their overall User Perception.

H2b: Tourists' Perceived Usefulness of AR-STGS positively influences their overall User Perception.

Following the integration of service quality and user perception, this study further investigates their direct influences on tourist satisfaction. Extant literature has consistently demonstrated that enhanced service quality substantially contributes to user satisfaction and acts as a pivotal determinant of tourists' cognitive appraisals [9]. Wilson et al. emphasized that when users perceive a platform as both easy to use and useful, they are more likely to experience positive emotional responses, which in turn shape their satisfaction with the overall service [10]. Derived from the theoretical framework and observed insights, the research advances the following hypotheses:

H3: Overall service quality has a positive effect on tourist satisfaction.

H4: User perception positively influences tourist satisfaction.

Moreover, satisfaction not only reflects a tourist's holistic approval of the service process but also significantly affects their emotional, cognitive, and behavioral responses—making it a key antecedent of tourist experience quality [11]. Research on mobile tourism applications further reveals that satisfaction enhances user trust, emotional identification, and perceived presence during the visit [12]. This is particularly critical in self-guided travel scenarios,

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where a satisfying digital service process often translates into a more fulfilling overall experience. In light of the preceding analysis, this study delineates the following hypotheses for verification:
H5: Tourist satisfaction positively influences the overall tourist experience.

3. METHODOLOGY

3.1 Research Context and Site Selection

To achieve methodological rigor and contextual diversity, the study relies on four nationally important heritage sites in China, each of which was chosen due to the uniqueness of its narratives and the different levels of AR-STGS deployment: the Palace Museum in Beijing, the Museum of the Terracotta Warriors in Xi an, the Liangzhu Ancient City Ruins Park in Hangzhou, and the Summer Palace, again in Beijing. These sites vary not only in terms of historical importance and the types of visitors they receive but also in the ways AR-STGS were integrated into their interpretive schemes. Together, they offer a comparative basis for understanding the relationship between AR-facilitated service delivery and user-centered outcomes across heterogeneous cultural tourism settings.

3.2 Questionnaire Design and Data Collection

Participants responded to all items using a standardized 7-point Likert-type scale, facilitating the quantification of attitudinal intensity. Data collection was conducted via a secure online platform. The target respondents were tourists aged 18 to 55 years who had actual usage experience with AR-STGS. This cohort was selected based on their dual characteristics of technological receptiveness and tourism consumption capability, positioning them well to provide credible evaluations of system performance and user-centered experiences. The study yielded 748 completed questionnaires for analysis. Following the elimination of low-quality entries — specifically, those submitted by respondents who had not experienced the four targeted cultural sites, had no interaction with AR-STGS, or completed the questionnaire in implausibly short time frames—a final dataset comprising 658 valid cases was established for subsequent analysis.
The sample exhibited a near-equal gender distribution, with 50.2% identifying as male and 49.8% as female. Most respondents fell within the 26–40 age range, reflecting a demographic concentration among young to middle-aged adults. Notably, the educational profile skewed toward higher education, with a large proportion of participants holding a bachelor's degree or higher, aligning with existing market research that indicates visitors to cultural destinations often exhibit strong preferences for immersive and intellectually engaging travel experience.

4. RESULTS

4.1 Measurement Model Evaluation

Different indices address different aspects of model-data correspondence, and their combined use promotes the soundness of assessment. As in common empirical practice, CFI values greater than 0.90 (better: close to or even beyond 0.95) indicate a good comparative fit [13]. A GFI value greater than 0.80 is usually construed as representing the least acceptable level of model adequacy [14]. Moreover, an RMSEA of less than 0.06 and an SRMR of less than 0.08 demonstrate that there is a small approximation error and residual bias [15]. Lastly, a CMIN/DF ratio of less than 2 indicates a superior fit, whereas ratios of up to 5 are acceptable in complicated model specifications [16]. This rigorous assessment framework provides a statistically sound basis for evaluating the structural integrity of the AR-STGS measurement model, ensuring that subsequent inferences regarding Tourist Experience, Service Quality, User Perception, and Tourist Satisfaction rest on a stable analytical foundation. The model exhibited satisfactory goodness-of-fit, meeting conventional thresholds across key indices, including CFI (> 0.90), GFI (> 0.80), RMSEA (< 0.06), SRMR (< 0.08), and a chi-square to degrees of freedom ratio of less than 5. The results substantiate the internal consistency and theoretical coherence of the measurement model, establishing a robust empirical basis for advancing the structural equation modeling.
The factor loadings for the measurement items range from 0.86 to 0.90, indicating a consistently strong representation of the underlying constructs. Prior studies have recommended a minimum loading threshold of 0.50, with preferred values exceeding 0.70, to ensure construct validity [17]. To ensure the robustness of the measurement model, a comprehensive evaluation of both convergent and discriminant validity was conducted. Composite

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reliability (CR) values fall between 0.90 and 0.94, surpassing the widely accepted benchmark of 0.70 and demonstrating excellent internal consistency. The computed values for average variance extracted (AVE) fall within the range of 0.75 to 0.79, exceeding the established threshold and thereby affirming strong convergent validity, well above the recommended minimum of 0.50, thereby supporting robust convergent validity. To establish discriminant validity, the square root of each construct's AVE was assessed in relation to its correlations with other constructs, ensuring adequate conceptual separation across the model. Taken together, these metrics affirm that the measurement instrument exhibits high psychometric robustness, demonstrating both conceptual precision and structural stability, while effectively capturing the core dimensions of the target constructs.

4.2 Structural Model and Hypothesis Testing

This study employed standardized path coefficients (β) to assess the strength of direct effects between latent constructs, following established practices in SEM. As shown in Figure 2, we conducted a comprehensive analysis of the structural model to empirically test the proposed hypotheses. The structural model exhibited strong empirical validity, as indicated by multiple fit indices: CFI = 0.99, GFI = 0.94, RMSEA = 0.026, and SRMR = 0.099. A chi-square statistic of 813.57 with 563 degrees of freedom indicated a good model fit, reaching statistical significance at $p < 0.001$. The resulting CMIN/DF was 1.445. Collectively, these indicators demonstrate a strong model-data fit, thereby reinforcing the theoretical soundness and explanatory capacity of the proposed framework.

The empirical findings reveal that the responsiveness of AR-STGS plays a critical and strongly positive role in shaping perceived service quality ($\beta = 0.50$, $p < 0.01$), validating Hypothesis H1c. Similarly, assurance significantly enhances perceived service quality ($\beta = 0.53$, $p < 0.01$), consistent with Hypothesis H1d. Empathy was found to exert a statistically significant and positive effect on the outcome variable ($\beta = 0.64$, $p < 0.01$), thereby supporting Hypothesis H1e. In addition, perceived ease of use emerged as a critical antecedent to overall system perception, demonstrating a robust positive effect ($\beta = 0.72$, $p < 0.01$), thereby validating Hypothesis H2a. Tourists' evaluation of ease of use also significantly enhanced their overall perception of the system ($\beta = 0.70$, $p < 0.01$), supporting the acceptance of Hypothesis H2b. The results highlight that perceived service quality in smart tourism contexts is strongly influenced by a constellation of service attributes, with responsiveness, assurance, and empathy emerging as particularly influential dimensions. Perceived ease of use emerged as a pivotal cognitive factor, exerting a significant influence on how users interpret and evaluate their interactions with AR-STGS.

The structural analysis extended to additional service quality dimensions and yielded nuanced insights. Tangibility, traditionally regarded as a key factor, demonstrated a marginal and statistically non-significant negative association with perceived service quality ($\beta = -0.01$, $p > 0.05$), thereby not supporting Hypothesis H1a. Reliability also failed to produce a significant effect ($\beta = 0.26$, $p > 0.05$), leading to the rejection of Hypothesis H1b. These results indicate that in AR-enhanced, self-guided tourism scenarios, conventional service quality constructs such as tangibility and reliability may lose relevance, likely due to their diminished perceptual prominence in digital environments. With respect to tourist satisfaction, both Perceived Service Quality ($\beta = 0.17$, $p < 0.01$) and User Perception ($\beta = 0.19$, $p < 0.01$) emerged as significant positive predictors, lending empirical support to Hypotheses H3 and H4, respectively. These findings underscore the importance of subjective user evaluations in shaping satisfaction outcomes.

Collectively, the validated structural model delineates how key attributes of AR-STGS contribute to tourist satisfaction through the mediating roles of Service Quality and User Perception. More importantly, the results illuminate the functional and emotional dynamics underpinning user experience, particularly the roles of interactivity, perceived trust, and affective engagement in constructing perceived value in immersive, technology-driven tourism contexts. Conversely, the limited roles of tangibility and reliability indicate a potential redefinition of classical service quality constructs in digital tourism environments. Notably, perceived ease of use not only enhanced tourists' evaluation of the system directly but also acted as a key antecedent in multiple pathways, emphasizing its catalytic function in the formation of positive user experiences. Ultimately, both perceived service quality and system perception were found to be strong predictors of tourist satisfaction, reinforcing the theoretical applicability of service quality frameworks within AR-enabled tourism and offering practical insights for the design and optimization of intelligent guide systems.

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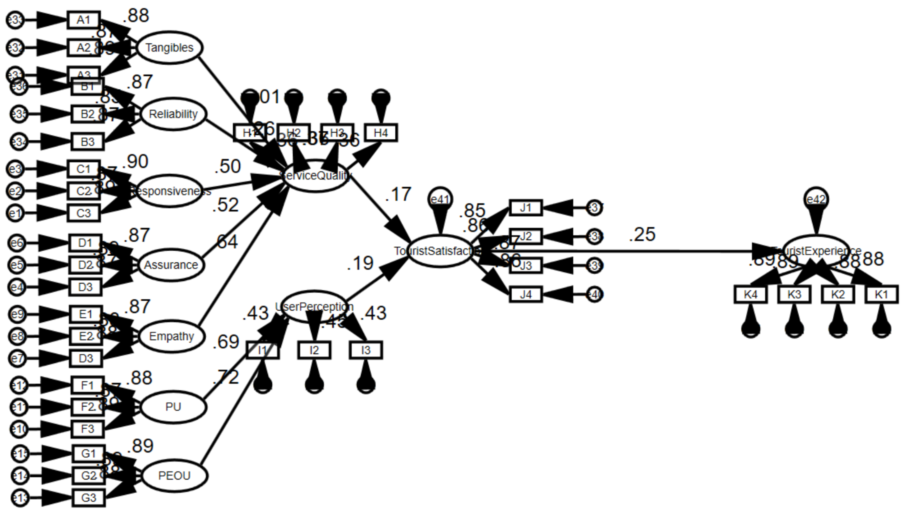

Figure 2. Path coefficients in latent variable models.

5. DISCUSSION

This study identifies key relational dimensions—namely, responsiveness, assurance, and empathy—as primary determinants of perceived service quality within the SERVQUAL framework when applied to AR-STGS. These findings indicate a clear shift in evaluative priorities among tourists engaging with technology-mediated services, with emotional support and interpersonal responsiveness emerging as more influential than traditional structural elements, such as tangibility and reliability. Such a shift reflects a broader evolution in user expectations, where immersive and emotionally attuned interactions outweigh physical design or procedural stability in shaping the tourist experience.

These outcomes reinforce central tenets of the TAM, highlighting usability as a foundational attribute in the acceptance and effectiveness of smart tourism technologies. Rather than relying solely on technical performance, adoption is shaped by a composite of emotional resonance, interaction quality, and overall satisfaction. For destination managers and system developers, fostering affective responsiveness and adaptive service dynamics appears more consequential to sustained value creation than infrastructural upgrades alone. Notably, in AR-enabled cultural tourism contexts, tourist satisfaction emerges not as a terminal outcome but as a pivotal link that translates system attributes into perceived experiential value. From a systems perspective, functionalities such as voice-responsive interaction, dynamic path guidance, and context-aware content presentation should be prioritized to strengthen user engagement and perceived responsiveness. Moreover, the integration of emotionally rich, culturally contextualized content—such as narrative-based storytelling and virtual character guidance—can foster a more empathetic and humanized experience. These elements help establish emotional resonance between the user and the system, supporting the design of affective, immersive journeys.

6. CONCLUSION

This research provides empirical insights into the mechanisms by which AR-STGS contribute to elevated levels of tourist satisfaction and enriched experiential engagement. By integrating theoretical constructs from both the SERVQUAL and TAM frameworks, a composite satisfaction model was developed and validated through empirical analysis. The findings underscore the importance of designing smart tourism systems that balance technical usability with emotionally attuned service features, thereby reinforcing the central role of user-centric experience design in immersive digital tourism environments. This study provides a novel theoretical perspective and empirical evidence for digital transformation and smart services in cultural tourism by demonstrating how user-centered and empathy-driven design in digital guide tools can facilitate sustainable cultural heritage engagement while reducing operational

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