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Augmented reality for ancient attractions

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ABSTRACT

The study focuses on augmented reality (AR) understanding, development and evaluation. For evaluation, this paper assesses the role of multimedia types in perceived enjoyment, and investing in how perceived usefulness, ease-of-use, and enjoyment affect the adoption of AR by tourists. A quantitative approach was employed to collect data from 115 participants who experienced an AR application designed for 14 ancient attractions in Songkhla, Thailand. The multimedia content included 3D models, historical videos, drone videos, billboard navigations, and text animations. Structural equation modeling (SEM) was used to test the proposed relationships. The findings revealed that perceived ease-of-use and enjoyment significantly influence behavioral intention (BI) as significant factors at 0.01, while perceived usefulness did not affect BI in the context of ancient attractions. Moreover, the multimedia types directly impacted the perceived enjoyment at a significant level of 0.05, and indirectly impacted BI. This study contributes to the theoretical understanding of AR adoption in tourism by integrating multimedia types with tourist perceptions and BI. Practically, it provides insights for designing AR applications that enhance visitor engagement and satisfaction in heritage tourism.

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1. INTRODUCTION

The rapid evolution of technology has revolutionized the tourism industry, providing travelers with innovative tools that enhance their experiences. Augmented reality (AR) has emerged as a transformative technology, offering immersive and interactive experiences by superimposing digital content on the physical world. In the context of tourism, AR applications have been widely adopted to deliver real-time information, create engaging narratives, and facilitate navigation at tourist destinations. At ancient attractions, AR has been instrumental in bringing historical narratives to life, enabling tourists to visualize reconstructed ruins, explore cultural heritage, and interact with historical contexts in ways that were previously impossible. Research on AR in tourism has focused on its technological capabilities and overall benefits to the user experience. Several studies have highlighted the role of perceived usefulness, perceived ease of use [1]–[3], and enjoyment in influencing the behavioral intention (BI) to adopt AR [2]–[5]. Additionally, the incorporation of multimedia types such as 3D models, animations and historical videos has been recognized to enhance user engagement and satisfaction [1], [6]. However, despite these advancements, the specific influence of multimedia types on tourist perceptions and their BI remains underexplored, particularly in the unique context of ancient attractions.

Ancient attractions, such as archaeological sites and cultural heritage landmarks, present distinct challenges and opportunities for AR integration. These sites often require the striking of a careful balance between the preservation of authenticity and the use of technology to enrich the visitor experience. While the ability of AR to reconstruct historical events and visualize ancient structures has proved its value, there is a limited understanding of the usefulness and ease of use of different multimedia types (*e.g.*, navigations, animations, 3D model historical videos, and drone videos) and enjoyment of visitors to historical sites. Furthermore, the role of these perceptions in persuading visitors to adopt AR offerings at ancient attractions has not been adequately investigated.

These limitations present a significant research gap in understanding how multimedia types of can influence tourist satisfaction and intentions, particularly in the unique context of ancient attractions, where AR applications could significantly enhance educational and cultural tourism. To address these gaps, this study aims to explore the role of multimedia types at the adoption of AR by tourists and their enjoyment of AR at heritage sites. Specifically, the study examines the relationships between multimedia types, perceived enjoyment, perceived usefulness, perceived ease of use, and BI to use AR in the context of cultural heritage tourism.

2. METHOD

The study focuses on AR understanding, development and evaluation. For research achievement, this section demonstrates the research methodology in Serven processes: i) Augmented reality understanding, ii) AR cloud services selection, iii) AR-adoption understanding and hypothesis development, iv) AR development, v) AR-route development, vi) Questionnaire development and data collection, and vii) AR-adoption evaluation. The details of these processes are presented as follows:

2.1. Augmented reality understanding

Augmented reality (AR) has emerged as a transformative technology in the tourism industry, offering immersive and interactive experiences that enhance visitor engagement and satisfaction. Applications of AR in tourism include virtual tours, cultural heritage storytelling, real-time navigation, and enhanced information displays at points of interest [7]–[10]. There are several types of AR digital content, including 3D models, animations, and videos. Despite its advantages, the use of AR in tourism faces several challenges such as technical limitations, user experience issues, cost and accessibility. Technical limitations can arise for geographical reasons. Even if advanced devices and high-quality graphics are available, the robust internet connectivity required by AR technologies may not always be available in remote tourist destinations. User experience issues can arise from poorly designed AR applications with complex interfaces, and technical glitches can discourage adoption. Finally, the costs of development and deployment can be expensive, limiting accessibility for smaller tourism enterprises.

2.2. AR cloud services selection

Table 1 presents a comparison of three AR cloud services: Arway (Corporate package), Artivive (Business package), and Arloopa (Education package for schools and universities). This study selected Arloopa services, based on its appropriate cost and project requirements, to develop an AR application for ancient attractions in Songkhla, Thailand. Since this service provider provided outdoor navigation, unlimited AR views, content types, interactive mapping, language translations, and cloud storage.

2.3. AR-adoption understanding and hypothesis development

AR has the potential to transform the tourism industry by creating immersive, educational, and convenient experiences. While challenges remain, the integration of AR with emerging technologies and an emphasis on user-friendly designs can drive its adoption. Most previous studies of AR adoption in tourism have focused mainly on the perceptions of tourists in three areas of interaction: perceived usefulness (PU), perceived ease-of-use (PE), and perceived enjoyment (PJ) [2], [3]. In the context of AR in tourism, PU and PE have often been linked to improved decision-making, enriched information delivery, and greater convenience [1]. Most studies have consistently shown that PU and PE significantly predicted BI to adopt AR technologies [2], [4]. For instance, when tourists perceive AR as a valuable tool for navigating unfamiliar destinations or learning about historical landmarks, their intention to use the technology increases [1], [2]. Nevertheless, a study of [8] found PU did not relate to tourists' BI on AR adoption. PE also impacted PU, because if AR applications were easy to navigate and use, tourists would be more likely to perceive them as enhancing their travel experience [1], [8]. Furthermore, PJ has been used to explain AR adoption by tourists. Enjoyable AR experiences, such as gamified treasure hunts or immersive storytelling, significantly enhance tourist satisfaction and engagement [1]–[3]. Based on a review of the literature, this study assumed the following hypotheses:

H1: PU positively influences BI to use AR *AncientCity@Songkhla*.
H2: PE positively influences BI to use AR *AncientCity@Songkhla*.
H3: PJ positively influences BI to use AR *AncientCity@Songkhla*.
H4: PE positively influences PU in the AR *AncientCity@Songkhla* usage.

Table 2 provides an overview of multimedia types (MTs) utilized in AR applications within various tourism contexts. Based on a review of prior studies [1], [6]–[11], [12]–[19], Table 2 categorizes multimedia into six types: navigations, historical videos, drone videos, 2D models, 3D models, and animations. The table also associates these MTs with specific tourism applications, such as heritage sites, hotels, museums, city guides, cultural and historical tourism, and purchasing behavior. Previous studies have highlighted that MTs can enhance user enjoyment [3], [9], intentions to use technology, and tourist satisfaction [12]. Consequently, this study considered five MTs for tourists: navigation, historical videos, drone videos, 3D models, and animations. As a result of the characteristics of the ancient buildings featured in this study, tourists possibly want to know about their size. Hence, a drone video was included in AR *AncientCity@Songkhla*, although most previous studies did not include this MT. MTs related hypotheses were formulated as follows:
H5: MTs positively influence BI to use AR *AncientCity@Songkhla*.
H6: MTs positively influence PJ.

Table 1. Comparison of AR cloud services (*Source: Authors, 2024*)

Feature	Arway	Artivive	Arloopa
Target and Audience	Business and tourism use AR indoor navigation and location information	Art exhibitions, Gallery, Museum, Artist, Digital art enthusiast	Business, Education, Marketing, Tourism, Game, General user
Views	1,000 views/month	15,000 views/month (Unlimited: add-on $2,115/artwork)	Unlimited AR views
Navigation	Indoor	Indoor	Indoor/Outdoor
Image content	✓	✓	✓
Video content	✓	✓	✓
3D models	✓	✓	✓
Texts	✓	✓	✓
Audio files	✓	✓	✓
Hotspots	✓	-	✓
Interactive map	✓	-	✓
Language translation	✓ (AI translation)	-	Additional option (Human translation)
Cloud storage	20 GB	5 MB	100 GB
Annual price	> $399	$88.04/cloud storage 5 MB	$399

Table 2. Multimedia types in AR for tourism

Context and reference	Navigation	Historical VDO	Drone VDO	2D	3D Model	Animation
Hotel [1]	✓	✓	-	-	✓	✓
Archaeological sites in India [6]	✓	✓	-	-	✓	-
Heritage sites [7]	✓	-	-	-	✓	-
Museums [8]	-	-	-	✓	✓	-
Heritage sites in Kastoria, Greece [9]	✓	✓	-	-	✓	✓
Tourist gaming in cultural sites [10]	✓	-	-	-	✓	✓
Cultural and heritage sites [11]	✓	✓	-	✓	✓	-
Cultural and heritage sites [12]	-	-	-	-	✓	✓
Tourist purchasing behavior [13]	-	-	-	-	✓	✓
Historical tourism [14]	✓	✓	-	✓	✓	✓
Cultural and heritage sites [15]	✓	-	-	-	✓	✓
Cultural tourism [16]	-	-	-	✓	✓	-
Historical sites [17]	-	-	-	-	✓	-
Cultural tourism [18]	-	-	-	✓	-	-
Indoor guidance system [19]	✓	-	-	✓	✓	-

2.4. AR development

The application developers included five multimedia types for tourists based on two technologies, as presented in Figure 1. The location-based AR was used to develop four feature types, including historical videos, drone videos, text animations, and 3D models. Meanwhile the AR marker-based using images on billboards was used to develop AR navigations. To support foreign tourists, the historical videos and AR navigations were provided in four languages (Thai, English, Chinese, and Malay). The Google Map API was integrated into AR navigations. The name of the developed application is AR *AncientCity@Songkhla*.

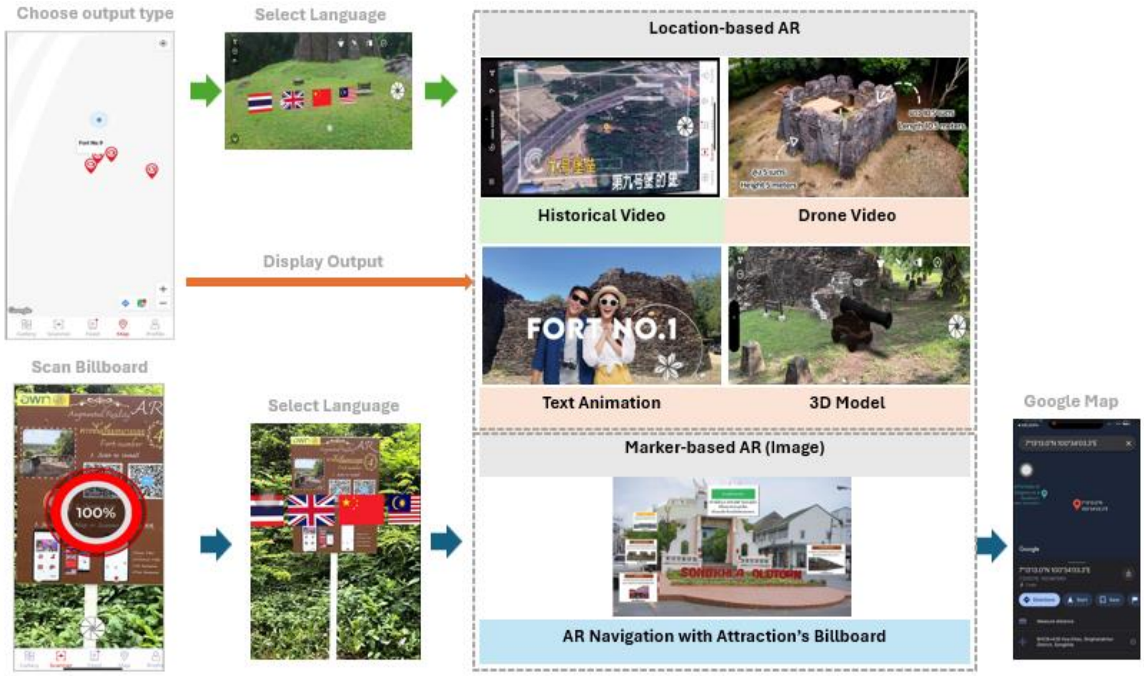

Figure 1. Examples of five multimedia types in AR *AncientCity@Songkhla* (*Source: Authors, 2024*)

2.5. AR-route development

The route selected for the development of the AR application used in this study comprised 14 significant ancient attractions in Songkhla, Thailand, including fortresses, city walls, and a city gate. The attractions are located at two sites separated by Songkhla Lagoon as presented in Figure 2: Boyang district (11 attractions) and Muang-Songkhla district (3 attractions). Tourists can visit these sites by ferry and land transportation.

Figure 2. Map of AR *AncientCity@Songkhla* as tourist destinations (*Source: Authors, 2024*)

2.6. Questionnaire development and data collection

This study employed a quantitative approach, using a survey questionnaire to collect data from 115 tourists. The sampling technique was convenience sampling, collecting data from volunteers who had experienced AR *AncienctCity@Songkhla* during visits in August 2024. The research instrument for data collection was a survey questionnaire. The questionnaire consisted of three sections:

- Demographic information,
- Information about five variables (PU, PE, PJ, MTs, and BI to use AR),
- Additional suggestions.

Participants were asked to indicate their agreement or disagreement with several statements on a five-point Likert scale (1=strongly disagree, 2=disagree, 3=not sure, 4=agree, and 5=strongly agree). In section 2 of the questionnaire, we adopted reliable measures from previous research [1], [7], [20]–[22], as shown in Table 3. All adopted items had values of Cronbach's Alpha or composite reliability (CR) higher than 0.70. There were 21 measures in four factors (PU, PE, PJ, MTs) and a dependent variable (BI).

Table 3. Research measurement

Item	Measurement	Item	Measurement
Perceived usefulness [1], [21], [22]		**Perceived enjoyment [20]–[22]**	
PU1	AR helped me learn history during trip.	PJ1	I was interested in using AR during the trip.
PU2	AR navigation was very useful for visiting destinations.	PJ2	I was excited using AR during the trip.
PU3	AR allowed me to access information quickly.	PJ3	I had fun with AR.
PU4	AR enhanced trip effectiveness.	PJ4	Using AR was a pleasurable experience.
Perceived ease-of-use [1], [21], [22]		**Behavioral intention [7], [21], [22]**	
PE1	AR was easy to use.	BI1	I intend to use AR in the future.
PE2	AR did not take time to learn.	BI2	I will use AR when I visit ancient attractions.
PE3	I could easily access the AR contents.	BI3	I will recommend others to use this AR.
PE4	The processes to use AR were not complex.	BI4	I will use AR navigation on my next trip.
Multimedia types			
MTs1	I like historical videos.		
MTs2	I like drone videos.		
MTs3	I like text animations.		
MTs4	I like 3D models.		
MTs5	I like AR navigations.		

2.7. AR-adoption evaluation

For adoption analysis, this study used software with a graphical user interface, namely SmartPLS, for structural equation modeling (SEM) in three processes: descriptive analysis, measurement analysis, and path analysis and hypothesis testing. The descriptive analysis specified the profiles of research volunteers such as gender, age, education, income, AR experiences, and opinion scores. The employed statistics of descriptive analysis were the mean, standard deviation, frequency, and percentage of frequency. With the aid of the measurement analysis, we evaluated convergent validity, reliability, and discriminant validity. Finally, path analysis provided the results of hypothesis testing using regression analysis.

3. RESULTS AND DISCUSSION

This section describes and discusses the results of this research and comprehensive discussion. There are included descriptive analysis, measurement analysis, and path analysis and hypothesis testing. The SmartPLS was the statistical tools to analyze in this study.

3.1. Descriptive analysis

In the demographic analysis, 115 complete questionnaires were analyzed using descriptive statistics. The proportions of males and females were 13.91% and 82.22%, respectively. The number of people aged 30 to 39 (109) was the largest among the population, accounting for 94.78% of the sample. In terms of mobile operating systems, 85 respondents used Android, accounting for 73.91% of the population. The proportion of respondents who had never had any experience with AR was more than half (57.39%). The proportion who had used AR 1-2 times was less than half as big (26.96%), and the proportion who had used AR more than 2 times was quite small (15.65%). Eighty-eight (88) participants (76.52%) had no prior experience with AR as a tourist, and only 27 participants (23.48%) had previously used AR as a tourist.

3.2. Measurement analysis

In the measurement analysis, SmartPLS was used to analyze convergent validity, reliability, and discriminant validity. Table 4 presents the results of the convergent validity and reliability analysis for the measurement. The analysis included factor loadings, Cronbach's Alpha, composite reliability (CR) in both *rho_a* and *rho_c*, and average variance extracted (AVE) to assess the internal consistency and convergent validity of the constructs. In summary, all constructs met the thresholds for convergent validity and reliability [23]–[28]. Factor loadings exceeded 0.70, Cronbach's Alpha and CR values were above 0.70, and AVE values were above 0.50, ensuring that the measurement model was robust and reliable. In addition, the primary criterion for discriminant validity was the Heterotrait-Monotrait ratio (HTMT), whose values were also less than 0.90 (0.864-0.888), indicating the discriminant validity of the constructs [29], [30].

Table 4. Results of convergent validity, reliability, and discriminant validity

Latent variable	Items	Mean	Std.	Convergent validity		Internal consistency reliability			Discriminant validity
				Loading	AVE	Cronbach's Alpha	CR (rho_a)	CR (rho_c)	HTMT
Indicator				>0.70	>0.50		0.60-0.90		<0.90
Perceived usefulness	PU1	4.31	0.872	0.881	0.780	0.906	0.906	0.934	Yes
	PU2	4.30	0.837	0.891					
	PU3	4.30	0.840	0.895					
	PU4	4.36	0.840	0.865					
Perceived ease-of-use	PE1	4.22	0.935	0.782	0.713	0.866	0.880	0.908	Yes
	PE2	4.17	0.936	0.842					
	PE3	4.17	0.927	0.900					
	PE4	4.18	0.884	0.849					
Perceived enjoyment	PJ1	4.33	0.889	0.838	0.774	0.902	0.905	0.932	Yes
	PJ2	4.36	0.879	0.931					
	PJ3	4.37	0.857	0.872					
	PJ4	4.33	0.842	0.876					
Multimedia types	MTs1	4.23	0.803	0.889	0.794	0.935	0.936	0.951	Yes
	MTs2	4.46	0.786	0.896					
	MTs3	4.34	0.787	0.889					
	MTs4	4.31	0.792	0.916					
	MTs5	4.32	0.864	0.866					
Behavioral intention	BI1	4.32	0.822	0.874	0.800	0.917	0.917	0.941	Yes
	BI2	4.25	0.907	0.886					
	BI3	4.32	0.822	0.900					
	BI4	4.34	0.782	0.918					

3.3. Path analysis and hypothesis testing

Using SmartPLS, the structural model evaluated the relationships among latent variables influencing the BI to use AR in tourism. The R-square value for BI was 0.857, indicating that 85.7% of the variance in BI can be explained by the combined effects of PJ, PU, PE, and MT. This is a strong level of explanatory power. The R-square value of PJ was 0.833, suggesting 83.3% of the variance in PJ was explained by its indicators (PJ1–PJ4). Furthermore, the R-square value of PU was 0.601, meaning 60.1% of its variance was explained by the indicators (PU1–PU4). Therefore, these R-square results indicated that the model provided a good fit for the data, suggesting that the proposed relationships in the model effectively capture the factors influencing the intention to use AR among tourists. The analysis included path coefficients (β values), and their respective significance (p-values) as presented in Figure 3.

The results indicated that PU had no direct significant impact on BI to use AR ($p = 0.973$). Thus, H1 was rejected. This relationship was negligible and not significant, which was consistent with the results from a previous study [8], even though most studies have found that PU influenced BI [1], [2]. Possibly because most our respondents were aged between 30 and 39 (94.78%), they preferred to take photographs for their interesting attractions, and hence did not focus on the usefulness of AR. PE had a significant positive effect on BI ($\beta = 0.303$, $p < 0.01$, f-square = 0.181), suggesting that ease-of-use was a key driver of AR adoption, this result supported H2, and was in line with the findings of other researchers [1], [2]. In addition, PE strongly and significantly influenced PU ($\beta = 0.775$, $p < 0.001$, f-square = 1.504), implying that an easy-to-use AR application was perceived as useful. Hence, H3 was accepted. These findings confirmed and explained AR adoption and loyalty behaviors across different contexts [1], [8]. PJ had a positive effect on BI. Therefore, H4 was accepted. This result illustrated that the enjoyment of AR can increase the intention to use it ($\beta = 0.349$, $p < 0.01$, f-square = 0.129) and supported the idea that PJ should be integrated in various sectors into theoretical frameworks for the adoption of emerging technologies, especially AR [1]–[3]. MTs showed a non-significant relationship with BI to use AR ($p = 0.075$). Thus, H5 was rejected at the significant value of 0.05, indicating that the variety and richness of multimedia content did not strongly predict an intention to use it. However, the results revealed that MTs strongly and significantly influenced PJ, indicating that enjoyment can enhance the variety and richness of multimedia experiences (β = 0.913, p <0.001, f-square = 4.978), supporting H6. This finding supported results from previous research [3], [9] that also highlighted the relationship between user enjoyment and MTs.

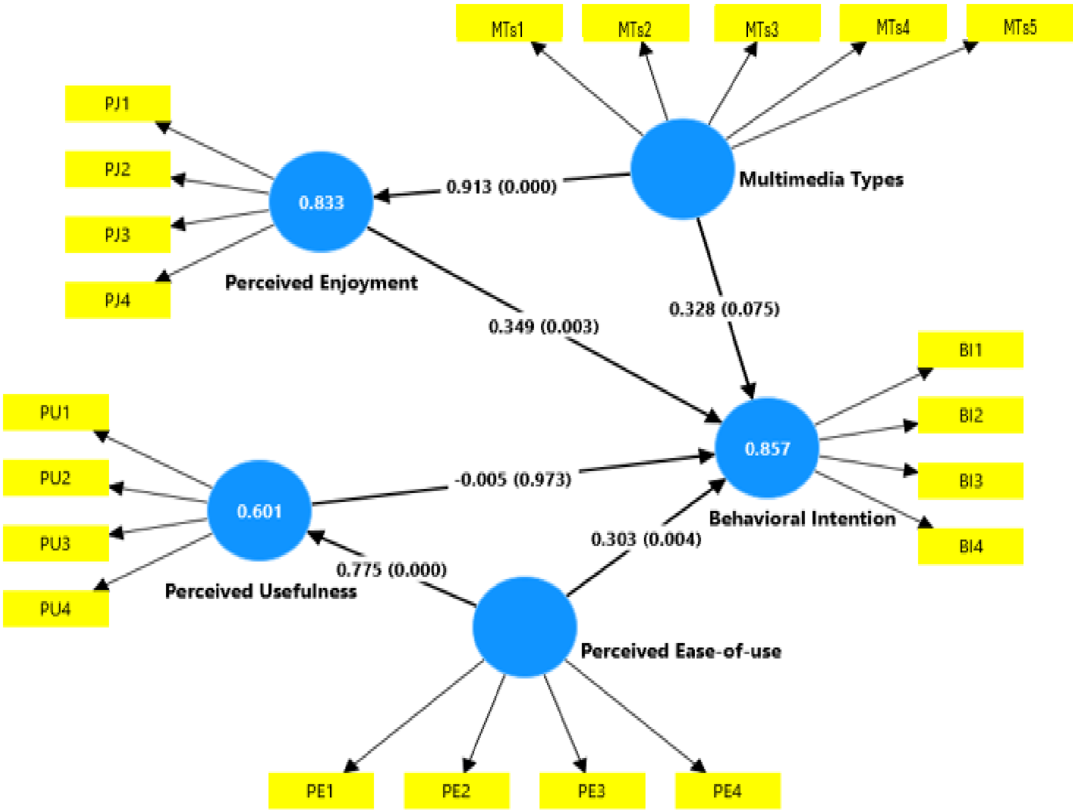

Figure 3. Results of path analysis

Figure 4 shows the dashboard of visitor preferences regarding historical attractions, AR features, and the integration of AR in specific locations. It also presents an evaluation of tourist satisfaction and the impact of AR on their experience. Fort #9 was the most popular attraction, with 50 users selecting it as their favorite location. Less popular places included Fort #12 (16 users) and Fort #15 (13 users). These findings indicate that tourists preferred to visit complete ancient constructions such as Fort #9, rather than ancient ruins such as Fort #12 and Fort #15 that are not visible in their original states. The most preferred AR types were 3D models and AR navigations, with 62.0% of users preferring them. Interactive and immersive AR features, such as 3D models and AR navigations, strongly appeal to users [6], [7], [12]. These tools likely enhance user engagement and provide a visually rich, dynamic experience. In contrast, historical videos were less popular features for AR at outdoor locations. One reason could be that the historical videos were too long (2-5 minutes), or perhaps it could be that tourists do not want to watch historical videos in the sun and use up a lot of their battery power. The comparison of historical videos and drone videos supported the likelihood of these possibilities, because all the drone videos were less than 20 seconds long. Furthermore, the findings also supported previous studies of city guides, cultural and historical sites [7], [14], [15], [16], [18]. As shown in Table 2, most previous studies provided AR navigations when they had travel routes in their projects.

The results highlighted several interesting issues concerning AR-type preferences across locations. First, 3D models were widely appreciated at Fort #9 (30 users), Lam Sai Fort (21 users), and Songkhla Gate (18 users). Second, AR navigations had strong engagement at Lam Sai Fort (27 users), Fort #9 (20 users), and Songkhla Gate (18 users). Third, drone videos influenced interest across multiple sites, peaking at Fort #9 (17 users). Fourth, historical videos were most used at Fort #9 (23 users) and Songkhla Gate (15 users). Finally, the use of text animations peaked at Fort #9 (26 users) and Lam Sai Fort (19 users). The favorite AR at each location provided two insights. Firstly, Fort #9, Lam Sai Fort, and Songkhla Gate consistently ranked high for AR feature engagement, suggesting that AR integration was effective at these locations.

Secondly, lower-performing sites (Fort #12 and Fort #15) may benefit from inclusion in immersive AR presentations.

Finally, the tourist satisfaction scores were different between two groups of tourists. Those who had previously experienced AR as tourists scored higher in terms of PU, PJ, and BI to use AR than those who had never previously experienced AR as tourists. In contrast, those who had never previously experienced AR as tourists were more satisfied in terms of PE. However, tourists in both groups were highly satisfied with AR *AncientCity@Songkhla*. This deepened understanding contributes to bridging knowledge gaps and enriching insights into the literature and helps developers better understand the underlying drivers of AR adoption in the context of outdoor attractions and historical sites.

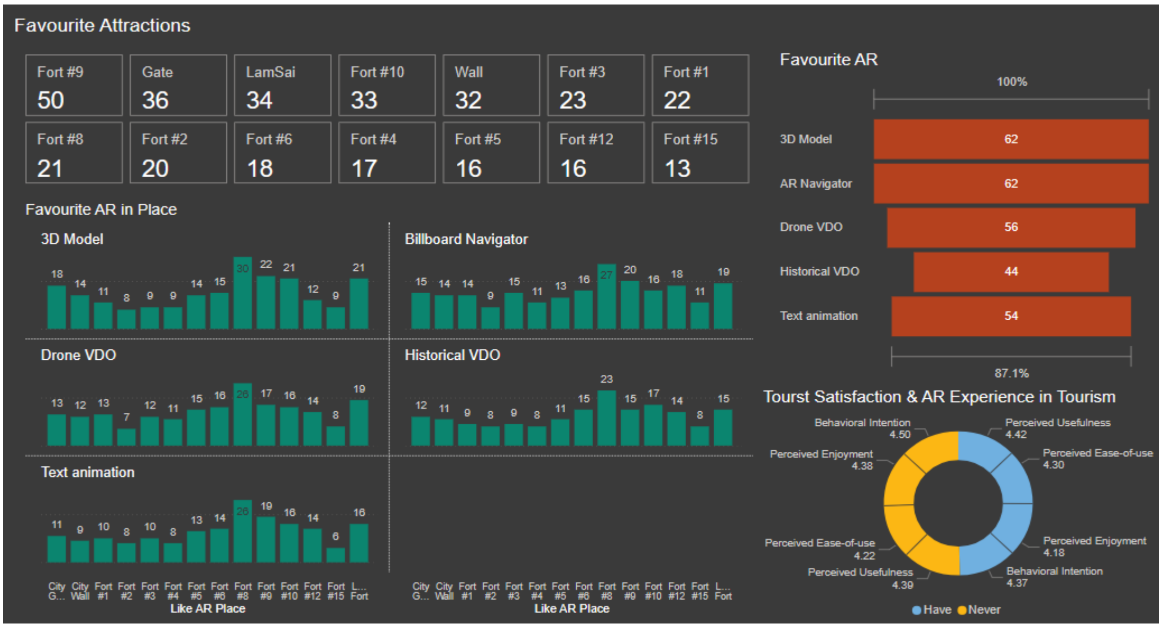

Figure 4. Tourist preferences and satisfaction scores

4. CONCLUSION

This study illustrated the important factors that encourage or discourage tourists to use augmented reality experiences at ancient attractions. Our findings contribute to the growing body of knowledge on AR in tourism by offering insights into how diverse multimedia elements enhance user experiences and foster positive behavioral intentions. The theoretical contributions made by this study include the findings that perceived ease-of-use and enjoyment are likely to increase the adoption of AR technologies at ancient tourist attractions. Furthermore, the multimedia types in an AR application can contribute to the enjoyment of the visit and indirectly influence behavioral intention. The findings provide not only theoretical contributions to the fields of AR technology and tourism but also practical implications for AR design to enrich visitor engagement at ancient tourist attractions and promote sustainable cultural heritage tourism. The practical contributions include actionable insights into the choice of multimedia features for effective AR development. In the context of cultural heritage tourism at open-air sites, tourists demonstrated a strong preference for interactive and immersive AR features such as 3D models and AR navigations rather than historical videos. Therefore, future developers should focus on improving the usability and enjoyment of AR applications and include 3D models and AR navigations to boost adoption in outdoor settings.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
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So : **So**ftware
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R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study were collected through field research and are available from the first author and corresponding author, NT. Due to privacy and ethical considerations, some data may be subject to access restrictions.

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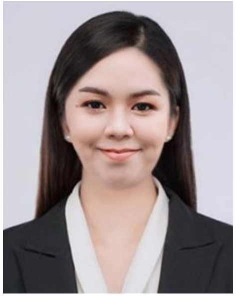

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