

EXPERIENCE ECONOMY AS A CATALYST FOR SUSTAINABLE GEOSITE TOURISM: SERVICE DESIGN MECHANISMS IN THE DUNHUANG DESTINATION SYSTEM, CHINA

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Abstract: This study examines how experience economy perceptions are associated with sustainable geosite tourism intention in Dunhuang, China, through service design mechanisms and place engagement. A cross-sectional visitor survey yielded 452 valid responses for PLS-SEM analysis, and semi-structured interviews with visitors and frontline staff were completed as contextual support for understanding destination touchpoints. The measurement model demonstrates satisfactory reliability and convergent validity, while discriminant validity is supported, with the EE-SDM HTMT value (0.8925) remaining below 0.90. The structural results show positive relationships for EE→SDM ($\beta=0.824$), SDM→SGTI ($\beta=0.385$), and EE→SGTI ($\beta=0.457$). The indirect association EE→SDM→SGTI is significant ($\beta=0.319$, 95% CI [0.241, 0.398]), and place engagement positively moderates the SDM→SGTI relationship ($\beta=0.184$, $p<.01$). The model therefore indicates that memorable destination experiences are linked to sustainable tourism intentions partly through visitors' perceptions of coherent, interpretable, and participation-oriented service design, with the strength of this relationship varying by place engagement. The study contributes a destination-system perspective that connects experience staging, service design, and sustainability-oriented intention across heritage, landscape, transport, and digital touchpoints. Managerially, the findings support touchpoint mapping, interpretive micro-experiences, coordinated digital-physical services, and context-sensitive stewardship cues across the Dunhuang destination network.

Keywords: experience economy, geotourism, geoheritage, service design, sustainable tourism, Dunhuang, destination system, PLS-SEM

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INTRODUCTION

Sustainable destination development increasingly depends on how destinations govern visitor flows and shape micro-level behaviour in situ. This challenge is acute in geosite tourism because many geological and desert landscapes are physically fragile, interpretation-intensive, and vulnerable to peak-season crowding. Meanwhile, tourism is in a period of accelerated digital transformation, where platforms, mobile services, and data-driven visitor management reshape both expectations and on-site operations (Buhalis et al., 2024; Reinhold et al., 2023).

Geoheritage and geotourism initiatives frame tourism as a pathway to geoeducation, conservation, and community benefit, yet systematic reviews show a gap between these aims and what is measured and managed. Many studies remain inventory- or assessment-centric, while fewer specify behavioural and service mechanisms that operationalise sustainability during the visit (Gupta et al., 2024; Rubira-Gómez et al., 2024).

This mechanism gap is echoed in tourists' environmentally responsible behaviour research. A recent systematic review concludes that while internal factors such as identity and emotions matter, situational factors—management quality, information timing, and place-based engagement—are reliably implicated in intention formation (Feng et al., 2024). Thus, sustainable outcomes depend on how experiences and services are designed, not merely on post-hoc messaging.

Dunhuang provides a distinctive case because it operates as a destination system where cultural heritage, desert geosites, transport infrastructure, and digital platforms jointly produce the visitor journey. Recent studies show that Dunhuang is actively developing digital heritage transformation and online tourism programs that extend the experience portfolio and can potentially redistribute demand (Hou et al., 2025; Yan et al., 2024). In parallel, desert tourism research finds that perceived value and awe can influence environmentally responsible behaviour through place attachment (Huang et al., 2025).

Heritage experience research at Mogao Grottoes further illustrates the role of narrative design: historical storytelling influences destination image and perceived value and subsequently revisit intention, with place attachment moderating parts of the mechanism (Yuxin et al., 2024). These strands suggest that experience and emotion are central to Dunhuang's tourism strategy. The unresolved question is how to harness them to produce sustainability outcomes beyond satisfaction and loyalty.

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Dunhuang's destination system can be understood as a network of interdependent experience arenas: world-class cultural heritage sites, desert geomorphology attractions, and supportive service nodes such as visitor centres, shuttles, and accommodation. In such systems, sustainability outcomes emerge from cumulative interactions across the journey rather than from a single site's policy. Destination management scholars emphasise that governance must account for multi-actor coordination, the sequencing of visitor encounters, and the dynamic reconfiguration of services in response to crowding, technology, and changing expectations (Reinhold et al., 2023). A key feature of Dunhuang is the coexistence of high-demand heritage experiences and expansive desert landscapes that invite immersion. This creates a tension between concentrated visitation pressure and dispersed visitation risk. Concentrated pressure threatens site integrity and visitor experience quality, while dispersed pressure can cause off-trail impacts if routing and norms are unclear.

The central management problem is therefore to choreograph access, attention, and movement in ways that preserve both experience value and landscape integrity. Digitalisation has become an increasingly visible element of Dunhuang's strategy. Digital heritage transformation can support conservation by enabling remote access, diversifying products, and improving visitor management. For example, work on digital Dunhuang discusses how digital technologies can help reconcile access and conservation by expanding interpretation and by improving management capabilities (Hou et al., 2025). Online tourism programs provide a concrete case of how digital touchpoints can change the sustainability calculus. The Yunyou Dunhuang program has been studied as an interactive virtual tourism experience integrated with learning outcomes and behavioural adoption intentions (Yan et al., 2024). Such programs can serve multiple functions: pre-visit education, substitute experiences for visitors who cannot access high-demand sites, and post-visit reinforcement to sustain learning and stewardship. Digital participation designs are also used to shape heritage experience states and participation. Research on serious games in cultural heritage shows that educational, entertaining, escapist, and aesthetic stimuli can improve perceived value and memory, which then drive participation intentions (Zhang et al., 2024). For Dunhuang, the design logic is transferable: game-like micro-experiences could encourage learning and responsible action without increasing physical wear on sensitive sites.

Finally, a destination-system lens foregrounds how digital and physical services must be integrated. Tourism technology reviews emphasise that adoption and benefits depend on interoperability and the alignment of technology with organisational routines and governance (Buhalis et al., 2024). This implies that sustainability is not delivered by digital tools alone, but by how those tools are embedded into the visitor journey and linked to clear stewardship behaviours.

In sum, Dunhuang illustrates a broader challenge: sustainable geosite tourism requires translating memorable experiences into feasible and meaningful stewardship intentions. This study addresses that challenge empirically by testing a destination-system model that links experience economy perceptions, service design mechanisms, place engagement, and sustainable geosite tourism intention among visitors in Dunhuang.

The experience economy provides the motivational and experiential layer of the model, while service design mechanisms represent the visitor-perceived organisation of touchpoints across the journey. The study tests a moderated-mediation model in which SDM mediate the association between EE and SGTI and PE moderates the SDM→SGTI relationship (Font et al., 2020; Daryanto & Song, 2020).

Experience economy research in tourism has matured over the past decade, moving from general claims about "memorable experiences" to measurable models that separate experience realms and test their behavioural consequences. The 4E logic has been applied across destination types, and recent SEM evidence across distinct destinations indicates that education, entertainment, and escapism often predict satisfaction and revisit/recommendation intention (Şeker & Unur, 2022). Heritage tourism studies link experience economy to authenticity and behavioural intention, highlighting that staged experiences operate partly through perceived value and emotional resonance (Zhu et al., 2025). Experience economy is therefore useful as a 'middle-range' construct: it is broad enough to capture holistic impressions, but structured enough to identify which experience realms need design investment. Experience economy is especially relevant in geoheritage contexts because geological features are "deep time" phenomena that require interpretive scaffolding. Interpretation-centre design research in geopark projects demonstrates how sustainability-oriented infrastructures can embed geoeducation and cultural meaning while maintaining harmony with natural conditions (Rubira-Gómez et al., 2024). Interpretation panels provide complementary micro-learning moments when they are readable, correctly placed, and designed around visitor decision points (Štrba & Palgutová, 2024).

Digital experience design expands the 4E toolkit. In cultural heritage, serious games can generate educational, entertaining, escapist, and aesthetic experiences that increase participation and memory—suggesting that digital micro-experiences can support engagement without adding physical pressure to sensitive sites (R. Zhang et al., 2024). Online tourism programs such as Yunyou Dunhuang deliver immersive and educational experiences through interactivity, showing how learning and escapism can be staged beyond physical presence (Tao, 2026; Yan et al., 2024).

From a sustainability lens, the key is how experience realms shape the cognitive and affective precursors of stewardship. Educational experience increases perceived understanding and legitimacy of rules; aesthetic experience can cultivate appreciation; entertainment can sustain attention; and escapism can heighten emotional connection. However, high-arousal escapism can also increase risk-taking unless constrained by design. Therefore, experience economy needs to be coupled with behavioural infrastructure to steer action, which motivates the service design variable.

Service design takes a journey perspective: it maps the visitor's experience across time and channels and then redesigns touchpoints to reduce friction, increase meaning, and deliver organisational goals. Tourism research increasingly recognises that destinations are service ecosystems where multiple stakeholders co-produce value, making coordination and orchestration essential (Gao et al., 2022; Reinhold et al., 2023).

From sustainable tourism's service-dominant logic, value co-creation can shift tourists from passive consumers to active stewards when institutional arrangements support transparency and shared purpose. Empirical work shows that co-creation is enhanced by clear role expectations, participatory opportunities, and consistent messaging across actors (Font et al., 2020).

For geosites, SDM include hard and soft design elements: trail and boardwalk layout, signage and interpretation sequencing, crowd management and timed entry, waste and water infrastructure, and the design of staff–visitor interactions. Geoheritage design studies emphasise that visitor centres and interpretation hubs can be conceived explicitly as sustainability tools that connect geosite value, geoeducation, and community benefit (Rubira-Gómez et al., 2024).

Digitalisation adds SDM levers such as reservations, route guidance, and micro-nudges delivered via mobile content (Li et al., 2022). Tourism technology reviews argue that successful adoption requires integration and interoperability across digital and physical systems (Buhalis et al., 2024). In Dunhuang, digital transformation work highlights how technology-enabled visitor management and digital heritage products can support sustainability outcomes when aligned with conservation goals (Hou et al., 2025).

We operationalise SDM as visitor perceptions that the destination's touchpoints are coherent, interpretive content is clear and consistent, infrastructure enables low-impact behaviour, and the destination invites participation in protection. This definition is both theoretically grounded and directly actionable in design practice.

Place engagement refers to visitors' attention, emotional resonance, and participation in a place. Engagement is closely linked to place attachment, which has been identified as a key predictor of pro-environmental behaviour. Meta-analytic evidence shows the overall effect of place attachment on pro-environmental behaviour is positive and moderate, and can vary by culture and place-user type (Daryanto & Song, 2020).

In Dunhuang, place processes are salient because the destination evokes strong emotions through both desert landscapes and cultural heritage storytelling. Empirical research shows that perceived value and awe influence environmentally responsible behaviour through place attachment in Dunhuang desert tourism (Huang et al., 2025; Permanadewi et al., 2026). Heritage storytelling mechanisms also involve place attachment as a moderator (Yuxin et al., 2024), reinforcing the view that engagement shapes behavioural translation.

We define SGTI as intention to: (1) comply with low-impact rules, (2) support conservation, and (3) choose sustainable service options. A systematic review of tourists' environmentally responsible behaviour indicates that such intention composites better capture sustainable tourism participation than narrow rule-compliance measures because they incorporate supportive behaviours and consumption choices (Feng et al., 2024).

We hypothesise that PE moderates the association between SDM and SGTI: visitors with stronger place engagement are expected to interpret service cues as more meaningful and to report stronger sustainability-oriented intentions. This moderation logic is consistent with the meta-analytic evidence base (Daryanto & Song, 2020) and Dunhuang-specific ERB evidence (Huang et al., 2025).

Experience economy studies show that visitors' perceptions of education, aesthetics, entertainment, and escapism are shaped by how destinations curate the visitor journey. Evidence across distinct destinations indicates that experience economy dimensions predict satisfaction and behavioural intention, suggesting that experience is tied to judgments about design and management quality (Şeker & Unur, 2022).

In geoheritage contexts, experience depends heavily on interpretive infrastructure. Interpretation centre design work illustrates how layouts, storytelling, and sustainability-oriented architecture can create coherence and meaning while protecting resources (Rubira-Gómez et al., 2024). Interpretation panel guidelines emphasise readability, placement, and narrative sequencing for learning and compliance (Štrba & Palgutová, 2024).

Dunhuang's digital transformation adds new touchpoints and changes how visitors form coherence judgments. Digital heritage transformation research suggests that technology can align experience with conservation by enabling better management and interpretation (Hou et al., 2025). Online programs, by providing interactive learning, can also reshape perceptions of service quality and coherence (Yan et al., 2024).

H1: Experience Economy (EE) is positively associated with Service Design Mechanisms (SDM).

Service design mechanisms should predict sustainable intentions because they structure the behavioural environment. Destination service ecosystem research argues that coherent journeys reduce uncertainty and make desired behaviour easier to enact (Gao et al., 2022). Destination management agendas emphasise measurement and tracking to regulate visitor flows and protect sensitive places (Reinhold et al., 2023).

In sustainable tourism, value co-creation is a key mechanism: when visitors perceive shared goals and legitimate constraints, they are more willing to accept management measures and participate in stewardship (Font et al., 2020).

Geoheritage design research provides practical examples: sustainable interpretation centres incorporate geoeducation, community consultation, and visitor management needs into their design, while well-designed panels support decisions at points where impacts occur (Rubira-Gómez et al., 2024; Štrba & Palgutová, 2024).

H2: Service Design Mechanisms (SDM) are positively associated with Sustainable Geosite Tourism Intention (SGTI).

Experience economy perceptions are expected to directly influence sustainable intention because people are more willing to protect what they value. In ecotourism scenic spots, tourist experience quality predicts pro-environmental behaviour and influences place dependence and identity, with place attachment acting as a mediator (J. Zhang et al., 2024).

In Dunhuang desert tourism, perceived value and awe influence environmentally responsible behaviour directly and indirectly through place attachment (Huang et al., 2025). These findings imply that meaningful experiences can increase willingness to comply with rules and support conservation, even when those rules constrain freedom. Heritage storytelling research supports the role of meaning-making: storytelling influences destination image and perceived value and

subsequently revisit intention, with place attachment moderating the mechanism (Yuxin et al., 2024). Although revisit intention differs from stewardship, both rely on perceived legitimacy and value, suggesting EE should predict SGTI.

H3: Experience Economy (EE) is positively associated with Sustainable Geosite Tourism Intention (SGTI).

Mediation specifies how experience perceptions translate into actionable intentions. Experience economy captures distal evaluations of staged experiences, while SDM capture proximate journey features that guide behaviour at decision points. This distinction aligns with destination ecosystem research, which emphasises that experiences emerge from coordinated touchpoints and backstage systems (Gao et al., 2022; Reinhold et al., 2023). Sustainable tourism co-creation research indicates that institutional arrangements transmit values into behaviour by creating participatory roles and consistent meanings (Font et al., 2020). Geoheritage reviews call for applied strategies that combine interpretation, infrastructure, and management rather than inventory only (Gupta et al., 2024). Therefore, SDM are expected to mediate EE's influence on SGTI. Practically, this means that improving experiences should increase sustainable intentions primarily when improvements occur through designable mechanisms such as interpretation clarity, route coherence, and co-creation invitations.

H4: Service Design Mechanisms (SDM) mediate the association between Experience Economy (EE) and Sustainable Geosite Tourism Intention (SGTI).

Engagement and attachment condition whether service cues are interpreted as meaningful norms. Daryanto & Song's (2020) meta-analysis shows that place attachment is a robust predictor of pro-environmental behaviour and that effects are shaped by culture and place-user type. In Dunhuang, attachment features in multiple mechanisms: it moderates parts of storytelling-based intention pathways (Yuxin et al., 2024) and mediates awe/value-based environmentally responsible behaviour (Huang et al., 2025). Thus, we hypothesise that place engagement strengthens SDM's effect on SGTI, because engaged visitors are more likely to internalise rules as expressions of the place's meaning and future wellbeing.

H5: Place Engagement (PE) positively moderates the association between Service Design Mechanisms (SDM) and Sustainable Geosite Tourism Intention (SGTI).

Geoheritage research has expanded rapidly, yet systematic reviews identify a recurring imbalance between assessment frameworks and behavioural mechanism studies. Applied sustainability strategies require connecting geoeducation and visitor experience to conservation behaviours at the point of visitation (Gupta et al., 2024).

Experience economy studies have produced robust evidence on satisfaction and loyalty, but sustainability outcomes are less consistently modelled, and the mediating role of service design remains under-tested in geosite tourism contexts (Şeker & Unur, 2022; Zhu et al., 2025).

Dunhuang research highlights digital transformation (Hou et al., 2025), online tourism programs (Yan et al., 2024), and narrative effects in heritage visitation (Yuxin et al., 2024), but fewer studies integrate these strands into a destination-system model of sustainable geosite tourism intention. This study addresses that gap through a moderated-mediation model centred on designable service mechanisms and place engagement.

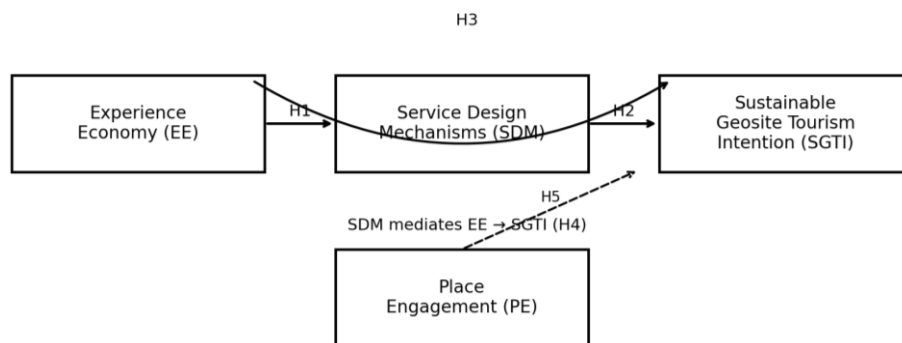


Figure 1. Theoretical Model

METHODOLOGY

The study employed a cross-sectional quantitative design centred on a visitor questionnaire. A total of 452 valid responses were included in the measurement-model assessment and structural-model estimation for Experience Economy (EE), Service Design Mechanisms (SDM), Place Engagement (PE), and Sustainable Geosite Tourism Intention (SGTI). Semi-structured interviews with visitors and frontline staff were also completed as a contextual component of the research. The questionnaire used a five-point Likert scale and was structured to distinguish experiential appraisal (EE) from service-design appraisal (SDM), while PE captured place-related attention, emotional connection, and involvement, and SGTI captured sustainability-oriented intentions. Participation was voluntary and anonymous, and no personally identifiable information was collected. Because the study is cross-sectional and perception-based, the structural paths are interpreted as theory-guided associations rather than causal effects. Reliability was assessed using Cronbach's alpha, Dijkstra-Henseler's rho (ρ_A), and composite reliability (ρ_c); convergent validity was assessed using AVE; and discriminant validity was evaluated using the Fornell-Larcker criterion and HTMT.

PLS-SEM was used to estimate the structural relationships. Statistical significance was assessed through bootstrap resampling; moderation was evaluated using the $SDM \times PE$ interaction term; and mediation was assessed through the specific indirect effect $EE \rightarrow SDM \rightarrow SGTI$. Model explanatory power was reported using R^2 and effect sizes (f^2), while predictive assessment was reported using Q^2 predict together with RMSE and MAE. All statistical values reported in the Results section are retained exactly as produced in the study analysis.

Structural paths are estimated with bootstrap resampling; moderation is tested using mean-centred interaction terms; predictive relevance is approximated via k-fold cross-validated Q^2 predict with RMSE/MAE error metrics.

Questionnaire profile

Table 1 presents the profile of the questionnaire used in this study. The individual questionnaire items are provided in Supplementary 1 (S1).

Table 1. Questionnaire profile (All constructs were measured on a 5-point Likert scale: 1 = Strongly disagree; 5 = Strongly agree)

Variable	Items	Sources
Experience Economy (EE)	Eight	(Şeker & Unur, 2022; Marciszewska & Wanagos, 2024; Zhu et al., 2025)
Service Design Mechanisms (SDM)	Six	(Font et al., 2020; Gao et al., 2022)
Place Engagement (PE)	Four	(Daryanto & Song, 2020; Huang et al., 2025)
Sustainable Geosite Tourism Intention (SGTI)	Five	(Feng et al., 2024; J. Zhang et al., 2024; Huang et al., 2025)

RESULTS

The PLS-SEM analysis was conducted using the 452 valid survey responses. The Results section reports the measurement model, discriminant validity, structural relationships, mediation, moderation, explanatory power, and predictive metrics. Statistical values are reported as obtained from the study analysis and are not re-estimated in this language-cleaning revision.

Variables reliability and validity

Table 2 indicates that all four constructs demonstrate strong internal consistency reliability and convergent validity. Specifically, Dijkstra–Henseler’s rho (ρ_A) ranges from 0.8699 to 0.9460, Jöreskog’s rho / composite reliability (ρ_c) ranges from 0.8955 to 0.9509, and Cronbach’s alpha (α) ranges from 0.8444 to 0.9410. These values exceed commonly accepted thresholds (≥ 0.70), suggesting that the items within each construct consistently measure the same underlying concept.

Convergent validity is supported because the average variance extracted (AVE) for each construct is above the recommended minimum of 0.50. The AVE values are 0.7078 (EE), 0.7007 (SDM), 0.6818 (PE), and 0.7222 (SGTI), implying that each latent construct explains a substantial proportion of variance in its indicators.

Table 2. Variables reliability and validity

Construct	Dijkstra-Henseler's rho (ρ_A)	Jöreskog's rho (ρ_c)	Cronbach's alpha(α)	AVE
Experience economy	0.9460	0.9509	0.9410	0.7078
Service design mechanisms	0.9240	0.9335	0.9145	0.7007
Place engagement	0.8699	0.8955	0.8444	0.6818
Sustainable geosite tourism intention	0.9162	0.9285	0.9038	0.7222

Estimated Model

Figure 2 presents the estimated measurement and structural relationships among Experience Economy (EE), Service Design Mechanisms (SDM), Place Engagement (PE), and Sustainable Geosite Tourism Intention (SGTI).

The model specification includes (1) a direct path from EE $\rightarrow$ SGTI, (2) an indirect/mediated path through SDM, and (3) a moderation effect where Place Engagement strengthens the relationship between SDM and SGTI.

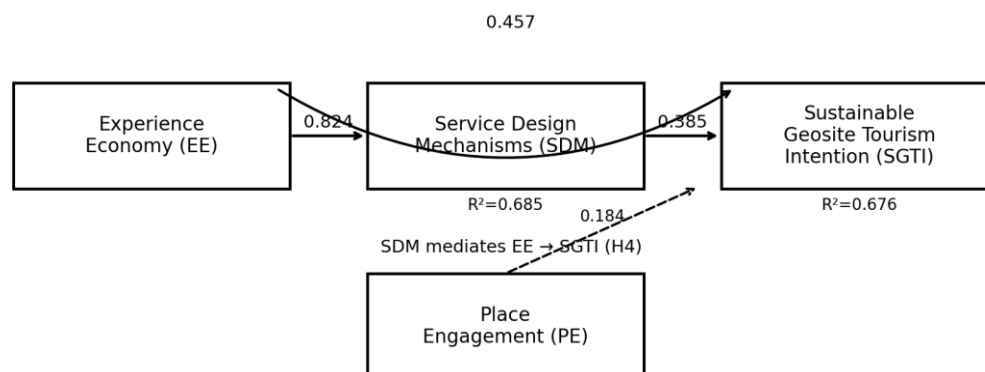


Figure 2. Estimated Model

Measurement Items Fitness Statistics

Table 3 shows that all indicators exhibit high outer loadings, supporting indicator reliability. The loadings for EE items (EE1–EE8) range approximately from 0.8236 to 0.8623, for SDM items (SD1–SD6) from 0.8237 to 0.8522, for PE items (PE1–PE4) from 0.8087 to 0.8353, and for SGTI items (SGT1–SGT5) from 0.8414 to 0.8577.

Because these loadings are all comfortably above the typical minimum criterion (≥ 0.70), the indicators are strongly associated with their intended latent variables and contribute meaningfully to construct measurement.

Table 3. Measurement items fitness statistics (outer loadings)

Indicator	Experience economy (EE)	Service design mechanisms (SDM)	Place engagement (PE)	Sustainable geosite tourism intention (SGTI)
EE1	0.8321			
EE2	0.8425			
EE3	0.8567			
EE4	0.8623			
EE5	0.8312			
EE6	0.8236			
EE7	0.8371			
EE8	0.8444			
SD1		0.8513		
SD2		0.8248		
SD3		0.8237		
SD4		0.8452		
SD5		0.8248		
SD6		0.8522		
PE1			0.8087	
PE2			0.8273	
PE3			0.8313	
PE4			0.8353	
SGT1				0.8577
SGT2				0.8499
SGT3				0.8561
SGT4				0.8437
SGT5				0.8414

Discriminant Validity

Discriminant validity is supported under the Fornell–Larcker criterion because the square root of AVE (diagonal values) for each construct is greater than its correlations with other constructs. For example:

EE has $\sqrt{\text{AVE}} = 0.8413$, which exceeds its correlations with SDM (0.8279), PE (0.5104), and SGTI (0.7642).

SDM has $\sqrt{\text{AVE}} = 0.8371$, which exceeds its correlations with EE (0.8279), PE (0.4397), and SGTI (0.7560).

PE has $\sqrt{\text{AVE}} = 0.8257$, exceeding correlations with EE (0.5104), SDM (0.4397), and SGTI (0.3803).

SGTI has $\sqrt{\text{AVE}} = 0.8498$, exceeding correlations with EE (0.7642), SDM (0.7560), and PE (0.3803).

Overall, this pattern indicates that each construct shares more variance with its own indicators than with other constructs.

Table 4. Discriminant validity (Fornell–Larcker criterion; diagonal = $\sqrt{\text{AVE}}$)

Construct	1	2	3	4
1. Experience economy	0.8413	0.8279	0.5104	0.7642
2. Service design mechanisms	0.8279	0.8371	0.4397	0.7560
3. Place engagement	0.5104	0.4397	0.8257	0.3803
4. Sustainable geosite tourism intention	0.7642	0.7560	0.3803	0.8498

Table 5. Discriminant validity (HTMT ratios)

Construct	1	2	3	4
1. Experience economy	-	0.8925	0.5726	0.8287
2. Service design mechanisms	0.8925	-	0.5004	0.8316
3. Place engagement	0.5726	0.5004	-	0.4353
4. Sustainable geosite tourism intention	0.8287	0.8316	0.4353	-

Table 5 further evaluates discriminant validity using the HTMT criterion. The HTMT values range from 0.4353 to 0.8925. Most ratios are well below 0.85, indicating clear separation among constructs. The EE–SDM HTMT = 0.8925 is below 0.90 but close to the upper boundary, implying that Experience Economy and Service Design Mechanisms are conceptually distinct but strongly related in this dataset—consistent with the idea that experience-oriented destination offerings are tightly tied to the way services are designed and delivered.

Variables effects overview

Table 6 summarizes direct, indirect, and total effects, along with effect sizes (Cohen's f^2) for key predictors of SGTI.

The path EE $\rightarrow$ SDM is strong and positive ($\beta = 0.8240$), indicating a substantial positive association between experience-economy perceptions and perceived service design mechanisms.

SDM $\rightarrow$ SGTI is positive ($\beta = 0.3853$, $f^2 = 0.141$), indicating a positive association between perceived service design mechanisms and sustainable geosite tourism intention, with an effect size around the small-to-moderate range.

EE $\rightarrow$ SGTI remains positive ($\beta = 0.4569$) with $f^2 = 0.198$, indicating a positive direct association between experience economy perceptions and sustainable intention when SDM is included in the model.

The interaction $\text{SDM} \times \text{PE} \rightarrow \text{SGTI}$ is positive ($\beta = 0.1841$, $f^2 = 0.136$), indicating that the positive association between SDM and SGTI is stronger at higher levels of place engagement.

The indirect effect of EE on SGTI via SDM is 0.3186, and the total effect of EE on SGTI is 0.7755. The indirect effect therefore accounts for approximately 41% of the total association reported in the model.

Table 6. Variables effects overview

Effect	Beta	Indirect effects	Total effect	Cohen's f^2
EE $\rightarrow$ SDM	0.8240	-	0.8240	-
SDM $\rightarrow$ SGTI	0.3853	-	0.3853	0.141
EE $\rightarrow$ SGTI	0.4569	0.3186	0.7755	0.198
$\text{SDM} \times \text{PE} \rightarrow \text{SGTI}$	0.1841	-	0.1841	0.136

R-square statistics Model Goodness of Fit Statistics

Table 7 indicates that the model explains a large share of variance in the endogenous constructs:

SDM has $R^2 = 0.6855$ (Adjusted 0.6848), suggesting that EE accounts for a substantial proportion of variance in service design mechanisms.

SGTI has $R^2 = 0.6762$ (Adjusted 0.6741), indicating that EE, SDM, and the interaction term collectively explain a substantial portion of sustainable geosite tourism intention.

Predictive assessment also appears strong: Q^2_{predict} values are 0.6828 (SDM) and 0.6700 (SGTI), both clearly above zero, supporting predictive relevance of the model. The reported prediction errors (RMSE and MAE) provide additional evidence of predictive performance (with lower values indicating better prediction).

Table 7. R-square statistics and predictive metrics

Construct	Coefficient of determination (R^2)	Adjusted R^2	Q^2_{predict}	RMSE	MAE
Service design mechanisms (SDM)	0.6855	0.6848	0.6828	0.6681	0.5310
Sustainable geosite tourism intention (SGTI)	0.6762	0.6741	0.6700	0.6918	0.5501

Path Analysis

Figure 3 (t-values on paths) and Table 8 (bootstrapped results) report positive and statistically significant relationships for all five hypotheses. EE denotes experience economy; SDM denotes service design mechanisms; SGTI denotes sustainable geosite tourism intention; and PE denotes place engagement. The interaction term $\text{SDM} \times \text{PE}$ represents the moderation test.

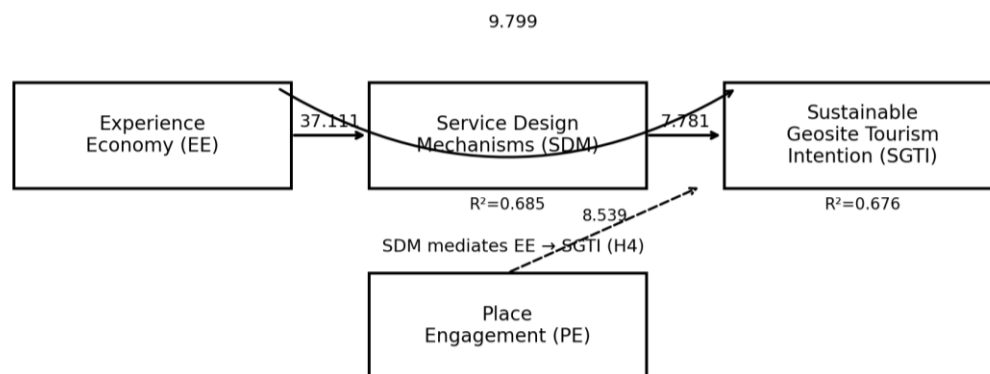


Figure 3. Structural Model for Path Analysis (t-values shown on paths)

Table 8. Structural model and path analysis results (bootstrapped)

	Original Sample	STDEV	T Statistics	P Values
H1: EE $\rightarrow$ SDM	0.8240	0.0222	37.111	0.0000
H2: SDM $\rightarrow$ SGTI	0.3853	0.0700	7.781	0.0000
H3: EE $\rightarrow$ SGTI	0.4569	0.0563	9.799	0.0000
H5: $\text{SDM} \times \text{PE} \rightarrow \text{SGTI}$	0.1841	0.0115	8.539	0.0000
H4: EE $\rightarrow$ SDM $\rightarrow$ SGTI (indirect)	0.3186	0.0408	7.810	0.0000

Direct effects

H1 (EE $\rightarrow$ SDM): $\beta = 0.8240$, $t = 37.111$, $p = 0.0000$

H1 (EE $\rightarrow$ SDM): $\beta = 0.8240$, $t = 37.111$, $p = 0.0000$

The relationship is positive and statistically significant, indicating a strong association between experience economy and perceived service design mechanisms.

H2 (SDM $\rightarrow$ SGTI): $\beta = 0.3853$, $t = 7.781$, $p = 0.0000$

Service design mechanisms are positively and significantly associated with sustainable geosite tourism intention.

H3 (EE $\rightarrow$ SGTI): $\beta = 0.4569$, $t = 9.799$, $p = 0.0000$

Experience economy is positively and significantly associated with sustainable geosite tourism intention after SDM is included in the model.

Moderation effect

H5 (SDM $\times$ PE $\rightarrow$ SGTI): $\beta = 0.1841$, $t = 8.539$, $p = 0.0000$

The positive interaction indicates that the positive association between SDM and SGTI is stronger when place engagement is higher.

Mediation (indirect effect)

H4 (EE $\rightarrow$ SDM $\rightarrow$ SGTI): $\beta = 0.3186$, $t = 7.810$, $p = 0.0000$

The indirect effect is statistically significant. Because the direct EE $\rightarrow$ SGTI path is also significant and positive, the pattern supports partial (complementary) mediation within the tested model: SDM accounts for part of the association between EE and SGTI while a positive direct association remains.

DISCUSSION

The discussion interprets the empirical associations identified in the cross-sectional PLS-SEM analysis. Because the design is cross-sectional and relies primarily on self-reported perceptions and intentions, the findings are discussed as theory-guided relationships rather than as evidence of causal effects or demonstrated conservation outcomes.

The empirical model is consistent with the proposition that experience economy perceptions are positively related to sustainable geosite tourism intention both directly and indirectly through service design mechanisms. EE is positively associated with SDM, and both EE and SDM are positively associated with SGTI. This pattern fits a destination-system logic in which memorable experiences and coherent service touchpoints operate together in shaping sustainability-oriented intentions (Gao et al., 2022; Font et al., 2020).

The strong EE $\rightarrow$ SDM association indicates substantial overlap in how visitors evaluate memorable experiences and the coherence of service design. Perceived journey coherence and interpretive clarity appear closely connected to the broader experience economy assessment. For managers, this suggests that backstage integration across transport, ticketing, crowd management, interpretation, and digital services may be relevant not only to experience quality but also to the formation of sustainability-oriented intentions (Hou et al., 2025; Reinhold et al., 2023).

The positive SDM $\rightarrow$ SGTI association indicates that sustainability-oriented intention is related not only to visitor attitudes but also to perceptions of the behavioural infrastructure surrounding the visit. Interpretation panels and centres, shuttle routing, timed entry systems, and staff communication can make low-impact options clearer and easier to follow (Štrba & Palgutová, 2024; Rubira-Gómez et al., 2024). The positive SDM $\times$ PE interaction further indicates that the association between service design mechanisms and SGTI is stronger among visitors reporting higher place engagement.

Engaged visitors respond more strongly to service cues, consistent with meta-analytic evidence linking attachment to pro-environmental behaviour (Daryanto & Song, 2020) and with Dunhuang findings showing place attachment mediates awe/value effects on ERB (Huang et al., 2025).

A journey-based lens clarifies how SDM operate. Pre-visit touchpoints—search results, booking confirmations, route recommendations, and micro-learning content—prime visitors' expectations and norms. In Dunhuang, digital heritage transformation is already part of the strategy, enabling destinations to deploy interpretation and behaviour prompts before visitors arrive (Hou et al., 2025). Online tourism programs provide another pre-visit (or substitute) touchpoint that can foster learning and pro-sustainability attitudes (Yan et al., 2024).

At arrival, SDM concern flow and clarity. Service ecosystem research emphasises that uncertainty and friction at queues and access points can trigger negative behaviour, whereas clear sequencing and consistent staff messaging reduce confusion and increase perceived legitimacy (Gao et al., 2022; Reinhold et al., 2023). In geosite settings, arrival design should include decision-point interpretation that explains why certain areas are closed or why boardwalks are mandatory. This reduces the perceived arbitrariness of constraints and increases voluntary compliance.

On-site, SDM and experience economy should be orchestrated together. Managers can intentionally stage an awe moment (a viewpoint or narrative) and immediately follow it with a specific conservation cue, such as a commitment prompt or a short learning moment that links the visitor's action to landscape vulnerability. Dunhuang evidence indicates that awe and value influence ERB through attachment (Huang et al., 2025), and storytelling research indicates that narratives shape perceived value and intentions (Yuxin et al., 2024). This suggests that prompt timing matters: rules delivered after emotional peaks may be more effective than rules delivered at random.

Post-visit, the journey continues through sharing and memory. Digital heritage products and online content can sustain engagement and turn visitors into advocates. AI-enhanced virtual tourism studies suggest that interactivity and knowledge acquisition in virtual experiences can influence pro-environmental behaviour through attitude mechanisms (Wu & Wang, 2025). For Dunhuang, this indicates that post-visit digital experiences could reinforce stewardship intentions, support conservation fundraising, and guide future behaviour among repeat visitors.

For experience economy to function as a sustainability catalyst, destinations need monitoring systems that connect experience metrics to conservation outcomes. Traditional tourism KPIs (arrivals, satisfaction) are insufficient for geosite management because they do not reveal whether visitor behaviour is compatible with site protection. A destination-system

approach therefore requires a dual dashboard: (1) experience indicators (4E perceptions, perceived coherence, emotional engagement) and (2) conservation behaviour indicators (trail compliance, waste management, support for conservation).

Experience indicators can be measured using short post-visit surveys and digital feedback tools. For example, the EE and SDM measures used in this manuscript can be embedded into mobile feedback prompts at exit points. Engagement indicators can be inferred from participation in digital micro-learning or from voluntary sharing of conservation messages. Such data can identify which touchpoints create meaning and which create frustration.

Conservation behaviour indicators can be measured through multiple methods. Direct observation and ranger reports can track off-trail incidents and litter. Digital tools can support counting and flow monitoring, but the design must respect privacy and ethics. In many destinations, aggregate density metrics and hotspot maps can be computed without identifying individuals. These monitoring practices align with destination management research that calls for measurement and tracking as core capabilities (Reinhold et al., 2023; Wang et al., 2022).

A useful evaluation strategy is to treat service design changes as experiments. When a new interpretive panel layout is installed, or when a digital pledge prompt is added to booking confirmation, managers can compare compliance and engagement indicators before and after implementation. Digital media research suggests that changing information format from text to vivid media can alter pro-environmental intentions (Chen et al., 2024). Similarly, AI-enhanced virtual tourism research suggests that interactivity and knowledge acquisition influence pro-environmental behaviour (Chae, 2026; Wu & Wang, 2025), indicating that digital interventions should be evaluated for both experience and behavioural effects.

Lastly, the roadmap should be embedded in governance. Destination systems require cross-actor alignment, shared metrics, and joint decision-making structures (Gao et al., 2022; Reinhold et al., 2023). For Dunhuang, this could take the form of an inter-operator sustainability steering group that meets regularly to review dashboard indicators, coordinate messaging, and approve service design changes. This institutionalisation ensures that SDM are not one-off projects but part of an ongoing capability—turning the experience economy into a durable catalyst for sustainable geosite tourism.

A segment-based strategy is crucial because place engagement moderation implies heterogeneity. Some visitors arrive already engaged and respond strongly to stewardship cues; others may be more instrumental and require clear routing and convenience. Segmenting by visitor type (first-time vs repeat, heritage-focused vs landscape-focused, group vs independent) allows managers to offer multiple pathways to stewardship. The Yunyou Dunhuang research shows that learning outcomes and planned behaviour constructs predict acceptance of online tourism programs (Yan et al., 2024), implying that digital segmentation could also personalise pre-visit learning and norms.

The moderated-mediation model can be translated into a practical implementation roadmap with four stages: diagnose, design, deploy, and learn. The diagnose stage maps the current journey and identifies where the experience economy is strong but sustainability behaviour is weak. Managers can combine observational data (hotspots, litter, off-trail incidents) with short exit surveys measuring EE, SDM, and PE. This responds to geoheritage review calls to move from assessment-only work toward applied, behavioural strategies (Gupta et al., 2024).

Institutional arrangements should include learning loops. The TERB literature emphasises that behaviour is shaped by situational cues and management quality (Feng et al., 2024). This implies that destinations should treat service design as continuous improvement: implement a touchpoint change, monitor behavioural indicators (off-trail incidents, waste), monitor experience indicators (4E perceptions, perceived coherence), and then iterate.

Destination management agendas explicitly call for such evidence-based, adaptive governance (Chae, 2026; Reinhold et al., 2023). In Dunhuang's context, integrating monitoring data across heritage sites and desert geosites can help identify which interventions generalise across the system and which require site-specific design.

An additional lever is integration of digital experiences with physical management. Online tourism programs can prime visitors before arrival and sustain engagement after departure, while also serving as substitute experiences when physical capacity is constrained (Yan et al., 2024). AI-enhanced virtual tourism research suggests that interactivity and knowledge acquisition can influence pro-environmental behaviour via attitudinal pathways (Wu & Wang, 2025).

However, these digital interventions produce sustainability benefits only when they are integrated into visitor management and conservation financing—for example, by linking virtual participation to conservation-support options, or by using digital channels to communicate real-time crowding and route alternatives (Hou et al., 2025).

Another lever is designing co-creation roles that are credible and rewarding. Sustainable tourism co-creation research argues that tourists' willingness to participate increases when roles are clear, voluntary, and connected to shared purpose (Font et al., 2020). In geosite tourism, co-creation can take the form of stewardship pledges, conservation donations, citizen-science photo monitoring, or guided 'leave-no-trace' challenges. Serious-game research in cultural heritage indicates that participation and memory increase when the experience is designed across 4E realms (R. Zhang et al., 2024). Translating this insight, Dunhuang could embed co-creation tasks into the journey as micro-experiences that enhance escapism and learning while reinforcing low-impact behaviour.

A further lever is coordination of interpretation and storytelling. The geosite context requires visitors to understand 'why'—why certain dunes are fragile, why boardwalks exist, why some viewpoints are closed. Geoheritage interpretation research provides guidelines on panel content and placement so that learning occurs at decision points (Štrba & Palgutová, 2024). At the same time, Dunhuang's heritage storytelling evidence shows that narratives can drive perceived value and intentions and that place attachment moderates how visitors respond (Yuxin et al., 2024). This suggests an institutional task: create a destination-wide story architecture that integrates geoeducation, cultural heritage, and sustainability norms, rather than leaving each operator to improvise messaging.

An institutional lever is governance of capacity and access. Destination management agendas highlight visitor-flow monitoring and adaptive regulation as core capabilities for sensitive places (Reinhold et al., 2023). In Dunhuang, where some sites require timed entry and shuttles, access governance can be framed as part of the premium experience rather than as a restriction. The experience economy lens supports such framing: capacity controls can be presented as enabling education (better guide attention), aesthetics (less crowding), and authenticity (protecting fragile settings). Digital heritage transformation work suggests that when technology supports transparent capacity information and personalised routing, visitors perceive management as competent and fair (Buhalis et al., 2024; Hou et al., 2025).

Destination systems require alignment across multiple actors, and service design interventions will fail if they are treated as isolated projects at a single attraction. In Dunhuang, the journey crosses institutional boundaries: heritage administration, scenic-area operators, transport providers, hospitality businesses, and digital-platform partners. Service ecosystem scholarship emphasises that value is co-created through interactions among these actors and that sustainability depends on institutional arrangements that make responsible behaviour easy and legitimate for visitors (Font et al., 2020; Gao et al., 2022). In practice, this means that the same rule, narrative, and behavioural cue should be expressed consistently across ticketing systems, signage, staff scripts, and digital content; otherwise, visitors experience ambiguity and interpret rules as arbitrary.

The first implication of this study is to treat touchpoint mapping and service blueprinting as conservation tools: identify where behavioural leakage occurs and redesign to make low-impact behaviour the default.

Secondly, interpretive layering and deliver geoeducation should be built at decision points using recommended panel practices and interpretation-centre design principles (Štrba & Palgutová, 2024; Rubira-Gómez et al., 2024).

Thirdly, use engagement sequencing. Create awe/storytelling moments first, then deliver behavioural prompts while engagement is high. This aligns with Dunhuang evidence linking awe/value to ERB via attachment (Huang et al., 2025) and with heritage storytelling mechanisms (Yuxin et al., 2024).

Finally, a phygital experience portfolio could be built. Online programs and digital heritage products can redistribute demand and extend learning; AI-enhanced virtual experiences can influence pro-environmental behaviour through attitudes and knowledge acquisition (Hou et al., 2025; Wu & Wang, 2025; Yan et al., 2024).

The study integrates experience economy, destination service ecosystem theory, and sustainable tourism co-creation by specifying SDM as a measurable mechanism layer. It also responds to geoheritage reviews calling for applied strategies by connecting designable touchpoints to sustainable behavioural intentions (Gupta et al., 2024).

CONCLUSION

In conclusion, this empirical study examined sustainable geosite tourism intention in Dunhuang, China, through a destination-system model linking Experience Economy (EE), Service Design Mechanisms (SDM), Place Engagement (PE), and Sustainable Geosite Tourism Intention (SGTI). Using 452 valid survey responses and PLS-SEM, the study found that EE was positively associated with SDM and SGTI, while SDM was positively associated with SGTI. The specific indirect effect through SDM was significant, supporting partial complementary mediation, and the SDM×PE interaction was positive and significant, indicating that the SDM-SGTI relationship was stronger at higher levels of place engagement. These findings show that experience and service design are closely connected within the Dunhuang visitor journey and that service mechanisms provide an analytically distinct pathway linking experiential appraisal with sustainability-oriented intention.

The study contributes to sustainable geosite tourism research by integrating experience economy, destination service-system logic, and place engagement within a single moderated-mediation framework. Rather than treating memorable experience as sufficient in itself, the model highlights the relevance of coherent touchpoints, interpretation, infrastructure, and participation opportunities. For destination management, the findings support the systematic mapping of pre-visit, arrival, on-site, and post-visit touchpoints; the coordination of digital and physical services; and the placement of clear stewardship cues at moments when visitors are most attentive and engaged. These implications concern the design of visitor journeys and should not be interpreted as evidence that specific interventions have already caused measurable conservation outcomes. The study also has methodological implications. The measurement results support the reliability and convergent validity of the four constructs, while the EE-SDM HTMT value indicates that their conceptual proximity should continue to be monitored in future applications. The cross-sectional design establishes theoretically informed associations but does not provide temporal ordering or strong causal identification. In addition, the primary outcome is intention rather than directly observed environmental behaviour. Future research can therefore strengthen external and causal inference through longitudinal or experimental designs, behavioural observation, repeated measurement across seasons, and comparisons across visitor segments and geosite settings. Overall, the evidence supports a destination-system perspective in which memorable experiences, service design, and place engagement are jointly relevant to sustainability-oriented tourism intention. The practical value of the framework lies in identifying where visitor experience design and stewardship-oriented service arrangements intersect, while the theoretical value lies in specifying SDM as a mechanism connecting broad experiential appraisal with sustainability-oriented intention under differing levels of place engagement.

Limitations and Future Research Directions

The study has several limitations. First, its cross-sectional design and reliance on self-reported perceptions and intentions limit strong causal interpretation and do not establish temporal ordering among EE, SDM, PE, and SGTI.

Second, the outcome measure captures sustainability-oriented intention rather than directly observed low-impact behaviour. Third, the conceptual proximity between EE and SDM requires continued attention, particularly because the EE-

SDM HTMT value approaches the commonly used 0.90 boundary. These limitations do not invalidate the reported associations, but they define the appropriate scope of interpretation.

First, intention measures should be complemented with behavioural and observational data (trail compliance, waste sorting, donation behaviour) and, where possible, visitor flow analytics recommended by destination management agendas.

Second, discriminant validity between conceptually adjacent constructs (EE and SDM) can be challenging; future work should test second-order and formative specifications and refine item wording.

Third, governance research should examine how institutional arrangements and stakeholder coordination enable or constrain service design change at system scale. Finally, future studies could test whether digital media presence and virtual experiences amplify place engagement and stewardship intentions, building on evidence that vivid digital formats can increase pro-environmental intentions and that AI-enhanced virtual tourism can influence PEB.

Supplementary items S1: Questionnaire profiles;

Experience Economy (EE): EE1: The visit helped me learn something meaningful about Dunhuang's landscapes and heritage; EE2: The experience increased my understanding of how desert landforms and ecosystems work; EE3: The visit was entertaining and held my attention throughout; EE4: The activities and interpretation made the visit enjoyable and lively; EE5: The visit felt immersive—I could escape my routine and feel 'in the place'; EE6: I felt actively involved rather than merely observing; EE7: The scenery and overall setting were aesthetically impressive; EE8: The atmosphere and design of the site(s) were visually pleasing and well-composed;

Service Design Mechanisms (SDM): SD1: The visitor journey (ticketing, transport, entry, routing) felt well organised and coherent; SD2: I always knew what to do next and where to go; SD3: Interpretation (signs, guides, digital media) made the rules and reasons for conservation clear; SD4: Staff and information channels delivered consistent messages about responsible behaviour; SD5: Facilities and infrastructure made it easy to behave responsibly (e.g., bins, boardwalks, shuttles); SD6: The destination invited me to participate in protecting the place (e.g., pledges, donations, volunteering);

Place Engagement (PE): PE1: I paid close attention to the place and its stories during the visit; PE2: I felt emotionally connected to Dunhuang's landscape/heritage while on site; PE3: I shared or wanted to share information about the place with others; PE4: I feel involved with what happens to this place in the future;

Sustainable Geosite Tourism Intention (SGTI): SGT1: I intend to follow site rules that protect the landscape (stay on trails, avoid sensitive areas); SGT2: I intend to minimise waste and environmental impact during my visit; SGT3: I am willing to accept management measures (timed entry, shuttle-only access) to protect the site; SGT4: I am willing to support conservation efforts (donate, volunteer, or advocate). SGT5: I would choose tourism products or routes that are designed to be low-impact.

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Use of Generative AI: ChatGPT (OpenAI) was used solely for language editing and grammatical refinement. All suggested changes were reviewed and approved by the authors, who take full responsibility for the final content of the manuscript.

List of abbreviations: 4E, education, entertainment, escapism, and aesthetics; AI, artificial intelligence; AVE, average variance extracted; CI, confidence interval; EE, experience economy; ERB, environmentally responsible behaviour; GenAI, generative artificial intelligence; GPS, Global Positioning System; HTMT, heterotrait–monotrait ratio; IRB, Institutional Review Board; KPI, key performance indicator; MAE, mean absolute error; ORCID, Open Researcher and Contributor ID; PE, place engagement; PEB, pro-environmental behaviour; PLS, partial least squares; PLS-SEM, partial least squares structural equation modelling; Q²predict, cross-validated predictive relevance statistic; QR, quick response; R², coefficient of determination; RMSE, root mean square error; SDM, service design mechanisms; SEM, structural equation modelling;

SGTI, sustainable geosite tourism intention; SOR, stimulus–organism–response; TERB, tourists’ environmentally responsible behaviour; α , Cronbach’s alpha; ρ_A , Dijkstra–Henseler’s rho; ρ_c , composite reliability.

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