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Visual Guidance Strategies for Low-Carbon Behaviour in Smart Scenic Spot Digital Wayfinding Systems: A Case Study of Qinhuangdao

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ABSTRACT Under the background of the "dual carbon" strategy and the integrated development of smart tourism, digital wayfinding systems in scenic spots, as the most frequent information touchpoints with tourists, possess significant potential for guiding public low-carbon behaviour. To the best of the author's knowledge, this study is among the first to systematically apply visual persuasion theory to low-carbon behaviour guidance in scenic spot digital wayfinding systems. Taking Shanhaiguan Scenic Spot in Qinhuangdao as a case study, this paper integrates visual persuasion theory with persuasive design theory to construct a three-dimensional visual guidance framework of "information content – visual form – interaction mode" and designs three sets of digital wayfinding interface prototypes with different guidance strategies (data-driven, emotion-driven, and social norm-driven). Through user testing and questionnaire surveys ($N = 32$), the results showed that the main effect of strategy type on low-carbon behavioural intention was not significant, $F(2, 62) = 0.02$, $p = .98$, $\eta^2 = .001$, with all three strategies yielding mean scores above the neutral point of 4 on a 7-point scale (data-driven $M = 4.75$, $SD = 1.68$; emotion-driven $M = 4.80$, $SD = 1.49$; social norm-driven $M = 4.78$, $SD = 1.62$). Notably, the emotion-driven strategy demonstrated a clear advantage in the preference ranking, accounting for 46.9% of all selections. This divergence between behavioural intention ratings and preference rankings suggests the possibility of different mechanisms underlying immediate decision-making and long-term preference formation. The study proposes a "stratified adaptation" low-carbon behaviour visual guidance strategy system, offering operable strategy references for the low-carbon design of smart scenic spot wayfinding systems and providing a new pathway for visual communication design to intervene in public energy-saving behaviour.

INDEX TERMS Digital wayfinding system; Low-carbon behaviour; Visual guidance strategies; Smart scenic spot; Persuasive design; Qinhuangdao

I. INTRODUCTION

A. RESEARCH BACKGROUND

In 2020, China explicitly proposed the strategic goals of "carbon peaking by 2030 and carbon neutrality by 2060" [1]–[3]. The tourism industry, as a vital component of the global economy, accounts for approximately 8% of total global carbon emissions [4]. As the core spatial carrier of tourism activities, scenic spots generate significant carbon emissions through internal transportation, accommodation, and catering [5], [6]. Promoting the low-carbon development of scenic spots is not only an inevitable requirement in response to the national dual carbon strategy but also an important pathway for the sustainable development of tourism [7], [8].

In recent years, with the in-depth advancement of "Internet + Tourism" and smart tourism construction, an increasing number of scenic spots have begun to deploy digital wayfinding systems [9]–[11]. Unlike traditional static signage, digital wayfinding systems integrate technologies such as touch interaction, dynamic content updates, positioning and navigation, and augmented reality, providing functions including real-time information push, personalised guidance, and interactive feedback [12]. These systems serve not only as navigation tools but have also become one of the most central information touchpoints between scenic spots and tourists [13].

Traditional methods of guiding public low-carbon behaviour have primarily relied on policy regulation and economic incentives [14]. However, behavioural science and communication research have demonstrated that the way information is presented has a significant impact on individual behavioural decisions [15], [16]. Through the strategic organisation of visual elements such as graphics, colour, and typography, visual communication design can effectively capture attention, convey information, evoke emotions, and ultimately facilitate behavioural change [17]. Digital wayfinding systems in scenic spots, as visual information carriers in public spaces, inherently possess the potential to guide tourists' low-carbon behaviour through visual design; yet, this potential has not been fully explored in current research and practice [18], [19].

B. PROBLEM STATEMENT

Although digital wayfinding systems have been deployed in many scenic spots, current design practice and research primarily focus on three functions: navigation guidance, cultural display, and service information [20], [21]. Existing research has paid insufficient attention to the "behavioural guidance" function of wayfinding systems, particularly lacking systematic exploration of "low-carbon behaviour guidance." Specifically:

Current scenic spot wayfinding systems take "directions" and "introduction" as their core functions and have not yet incorporated "low-carbon behaviour guidance" into their design objectives [22]. A wayfinding system is not merely an information transmission tool but can also serve as a "soft intervention agent" for spatial behaviour. Through strategic information presentation, wayfinding systems have the potential to influence tourists' route choices, travel modes, and consumption behaviours [23], thereby reducing the overall carbon emissions of scenic spots.

How can low-carbon behaviour guidance information be effectively embedded into digital wayfinding systems? What visual design strategies should be adopted? How can information content, visual form, and interaction mode be coordinated? These questions lack systematic answers in the existing literature [24], [25]. There is currently a lack of empirical data based on user testing regarding the actual effects of different visual guidance strategies and which strategy is more persuasive in scenic spot scenarios [26]. Based on the above analysis, this paper proposes the core research question: How can visual design strategies in smart scenic spot digital wayfinding systems effectively guide tourists' low-carbon behaviour?

C. RESEARCH OBJECTIVES AND SIGNIFICANCE

To integrate visual persuasion theory and persuasive design theory to construct a visual guidance strategy framework for low-carbon behaviour in scenic spot digital wayfinding systems.

To design digital wayfinding interface prototypes with low-carbon guidance functions, taking Shanhaiguan Scenic Spot in Qinhuangdao as a case study.

To systematically compare, through user testing, the effects of three visual guidance strategies (data-driven, emotion-driven, and social norm-driven) on tourists' low-carbon behavioural intentions.

To propose a generalisable low-carbon behaviour visual guidance strategy system and design specifications based on empirical findings.

Research Significance:

At the theoretical level, to the best of the author's knowledge, this study is among the first to integrate visual persuasion theory and persuasive design theory and apply them to scenic spot wayfinding systems as a novel public medium [27]–[29]. The constructed three-dimensional framework of "information content – visual form – interaction mode" provides an operational analytical tool for understanding how visual design in public spaces can influence public environmental behaviour [30], [31]. Furthermore, this study identifies a divergence between behavioural intention ratings and preference rankings, contributing new experimental evidence to the cross-disciplinary topic of "design-driven behavioural change."

At the practical level, this study provides empirically based design strategy recommendations and design exemplars for the low-carbon upgrading of scenic spot digital wayfinding systems, offering decision-making support for scenic spot managers, wayfinding system design enterprises, and cultural tourism authorities.

D. RESEARCH METHODS

This paper adopts the following research methods:

TABLE 1. Research methods and uses

Method	Specific use
Literature research	Systematically review previous studies on visual persuasion theory, persuasive design theory, low-carbon behavior intervention, and scenic spot wayfinding systems, so as to establish the theoretical foundation of this research.
Case analysis	Take Shanhaiguan Scenic Spot in Qinhuangdao as a typical case to analyze the current status of its digital wayfinding system and its potential for guiding low-carbon behavior.
Design practice	Design three groups (6 prototypes in total) of digital wayfinding interfaces–data-driven, emotion-driven, and social norm-driven–based on the three-dimensional visual guidance framework.
User testing	Recruit 32 participants and adopt a one-way within-subjects design to test the effects of different visual guidance strategies on tourists' low-carbon behavioral intentions.
Questionnaire survey	Collect participants' demographic information, low-carbon behavioral intention ratings, and strategy preferences through an online questionnaire.
Statistical analysis	Conduct repeated measures ANOVA to compare the effects of the three strategies.

E. PAPER STRUCTURE

The subsequent chapters of this paper are organised as follows: Chapter 2 presents the theoretical foundations and literature review; Chapter 3 describes the research design and methods; Chapter 4 reports the experimental results and analysis; Chapter 5 constructs the low-carbon behaviour visual guidance strategies; and Chapter 6 concludes the study.

II. THEORETICAL FOUNDATIONS AND LITERATURE REVIEW

A. RESEARCH STATUS OF SCENIC SPOT DIGITAL WAYFINDING SYSTEMS

A wayfinding system refers to an information guidance system that assists people in spatial environments with positioning, determining directions, and reaching destinations [32]. With the development of digital technologies, digital wayfinding systems have integrated technologies such as touch interaction, dynamic content updates, and positioning and navigation, and have gradually become widespread in scenic spots [33], [34]. Existing research has categorised their functions into three types: navigation guidance (map browsing, route planning), cultural display (scenic spot introduction, AR interaction), and service information (ticket prices, facility locations) [35]. However, against the backdrop of low-carbon tourism and sustainable development, the “behavioural guidance” function of wayfinding systems–particularly guiding tourists to choose low-carbon touring modes–has not yet received systematic research attention [36]. This study addresses this gap.

B. RESEARCH STATUS OF SCENIC SPOT DIGITAL WAYFINDING SYSTEMS

Persuasion refers to the process of changing others’ attitudes, beliefs, or behaviours through information communication [37]. Visual persuasion specifically refers to achieving persuasive purposes through visual elements such as images, colour, and typography. Messaris (1997) identified three unique persuasive characteristics of visual images: iconicity (visual similarity to the referent, facilitating understanding and memory), indexicality (the evidentiary force of images as traces of the real world), and syntactic indeterminacy (images do not contain explicit logical connectors and can thus implicitly convey viewpoints without easily triggering counter-arguments from the audience) [16]. In the field of environmental communication, transforming abstract carbon emission data into visualised charts has been shown to significantly enhance the public’s carbon awareness and low-carbon behavioural intentions [22], [38]; however, existing research has predominantly focused on print advertisements and social media, paying less attention to the visual persuasion mechanisms of digital media in public spaces, such as wayfinding systems. To the best of the author’s knowledge, this study is among the first to introduce visual persuasion theory into scenic spot wayfinding systems as a novel public medium, thereby extending the application boundary of the theory.

C. PERSUASIVE DESIGN THEORY

The Fogg Behaviour Model (FBM), proposed by Fogg (2003), posits that the occurrence of a target behaviour requires the simultaneous fulfilment of three conditions: motivation, ability, and a trigger ($B = M \times A \times T$) [18], [39]. Applying this model to the scenic spot low-carbon behaviour guidance scenario: at the motivation dimension, the attractiveness of low-carbon behaviour can be enhanced through visual design (such as showcasing natural beauty or emphasising health value) [40]; at the ability dimension, the perceived difficulty of low-carbon options can be lowered through information visualisation [41]; and at the trigger dimension, low-carbon guidance information can be pushed at key decision nodes such as scenic spot entrances and traffic forks [42].

Based on the FBM, this study classifies low-carbon behaviour visual guidance strategies into three types: data-driven (appealing to rational cognition, using data charts and carbon emission comparisons) [43], emotion-driven (appealing to emotional resonance, using natural beauty imagery and poetic copy) [44], and social norm-driven (appealing to conformity, using crowd icons and percentage data) [25], [45]. To the best of the author’s knowledge, this study is among the first to systematically compare the differential effects of these three strategies in the context of scenic spot digital wayfinding within a single experimental framework.

D. CONSTRUCTION OF THE THREE-DIMENSIONAL VISUAL GUIDANCE FRAMEWORK

Integrating visual persuasion theory and persuasive design theory, this study constructs a three-dimensional framework of “information content – visual form – interaction mode.” The originality of this framework lies in its synthesis of two independent theoretical systems into an operational design analysis tool, thereby addressing the deficiency of theoretical integration in existing research [31], [46]:

TABLE 2. Three-dimensional visual guidance framework

Dimension	Core question	Design elements	Theoretical basis
Information content	What to say?	Low-carbon prompts, carbon emission data, social norm information, route comparison	Fogg Behavior Model, Social Norm Theory
Visual form	How to say it?	Icon style, color scheme, layout, data visualization format, illustration style	Visual Persuasion Theory
Interaction mode	How to interact?	Dynamic data updates, touchscreen interaction, check-in feedback	Persuasive Design (trigger mechanism)

The three dimensions of this framework act synergistically: information content provides the rational basis for behavioural choice, visual form enhances the attractiveness and persuasiveness of information, and interaction mode provides triggers and feedback at critical decision moments. This framework provides the theoretical guidance for the subsequent interface prototype design.

III. RESEARCH DESIGN AND METHODS

A. CASE SELECTION

This study selected Shanhaiguan Scenic Spot in Qinhuangdao as the research case based on the following considerations:

First, representativeness. Shanhaiguan is a national 5A-level scenic spot, the eastern starting point of the Ming Great Wall, known as the “First Pass Under Heaven,” receiving over five million visitors annually (Qinhuangdao Municipal Bureau of Culture and Tourism, 2024) [47], and possesses strong representativeness among historical and cultural scenic spots.

Second, wayfinding system infrastructure. Shanhaiguan Scenic Spot has actively promoted smart scenic spot construction in recent years and has deployed some digital wayfinding facilities, providing a realistic foundation for the research.

Third, low-carbon behavioural space. The core touring area of the scenic spot covers approximately 1.8 square kilometres [47], containing multiple route segments where visitors can choose between walking, cycling, battery cars, or taxis, thus presenting rich low-carbon behaviour guidance scenarios.

Fourth, research convenience. The researcher's institution is located in Qinhuangdao City, facilitating field investigation and material collection.

Shanhaiguan is located in the northeast of Qinhuangdao City, Hebei Province, serving as a strategic passage connecting Northeast and North China. The core touring area of the scenic spot includes attractions such as the First Pass Under Heaven Tower, the ancient city wall, Laolongtou (Old Dragon's Head), and the Mengjiangnu Temple. The main modes of internal transportation within the scenic spot include walking, sightseeing battery cars, and shared bicycles.

B. INTERFACE PROTOTYPE DESIGN

This study selected two typical "low-carbon behaviour decision points" within Shanhaiguan Scenic Spot as design scenarios:

TABLE 3. Design scenarios and low-carbon behavior decision points

Decision point	Location	Low-carbon option	Alternative option
Decision Point A	Scenic spot entrance plaza	Walk through the ancient city (approx. 2.5 km, 40 min)	Take a battery car (approx. 2.5 km, 10 min, ¥10/person)
Decision Point B	Fork road from Shanhaiguan Pass to Laolongtou	Cycle to Laolongtou (approx. 3 km, 15 min, shared bike)	Take a taxi or battery car (approx. 3 km, 8 min, ¥15–20)

Based on the three-dimensional visual guidance framework constructed in Chapter 2, this study designed three sets of interface prototypes with different strategies. The three sets of strategies maintained consistency in common information modules (scenic spot logo, current location, date and weather, navigation map, QR code) while only forming differentiated designs in the "low-carbon guidance information module":

The information content comprised carbon emission comparison data (walking/cycling 0 kg CO_2 vs. battery car/taxi 0.3/0.9 kg CO_2) and route distance and time comparisons; the visual form employed carbon footprint comparison charts, with stark contrasts between green (low-carbon) and grey/orange (high-carbon), and large, prominent numbers; the persuasion mechanism was cognitive persuasion [43].

Strategy A: Data-driven. The information content comprised carbon emission comparison data (walking/cycling 0 kg CO_2 vs. battery car/taxi 0.3/0.9 kg CO_2) and route distance and time comparisons; the visual form employed carbon footprint comparison charts, with stark contrasts between green (low-carbon) and grey/orange (high-carbon), and large, prominent numbers; the persuasion mechanism was cognitive persuasion [43].

Strategy B: Emotion-driven. The information content comprised emotive copy (e.g., "Measure the ancient city with your footsteps, let your breath be freer"); the visual form employed natural beauty illustrations or photography, with warm and soft natural tones (warm green, goose yellow, sky blue, off-white), and handwriting or serif style fonts; the persuasion mechanism was emotional persuasion [44].

Strategy C: Social norm-driven. The information content comprised social norm information (e.g., "85% of visitors choose to walk"); the visual form employed crowd icon arrays with large percentage numbers, combining gold (social proof) and green; the persuasion mechanism was social persuasion [25], [45].

1) Interface Prototype Production

Based on the above design specifications, the researcher completed all six digital wayfinding interface prototypes in PowerPoint. All interfaces adopted a unified canvas size of 1080×1920 pixels (portrait), consistent with the display ratio of current mainstream vertical wayfinding screens. The detailed design specifications are documented in a separate technical document and are not reiterated here for brevity.

C. USER TESTING DESIGN

Through convenience sampling, 32 participants were recruited, including undergraduate students in design-related majors, colleagues, and family members of the researcher. The sample comprised 13 males (40.6%) and 19 females (59.4%), with an age range of 18–60 years. All participants had normal or corrected-to-normal vision and the ability to operate a smartphone or computer normally.

The participants constituted a convenience sample, and differences may exist compared to actual scenic spot tourists in terms of age, educational background, and travel motivations. The primary reasons for employing a convenience sample were threefold:

(1) this study is a theory-driven mechanism test, and the core psychological processes of visual persuasion and behavioural intention possess relative stability across adult populations [48];

(2) the homogeneity of a convenience sample helps reduce random error, which is advantageous for establishing clear causal relationships in the early stages of research [49];

(3) limited research resources and time constraints made conducting a controlled experiment with an accessible sample feasible. The limitations of the sample selection are further discussed in Chapter 6.

The test materials included six interface prototype images (JPG format) and an online questionnaire. The test procedure was as follows:

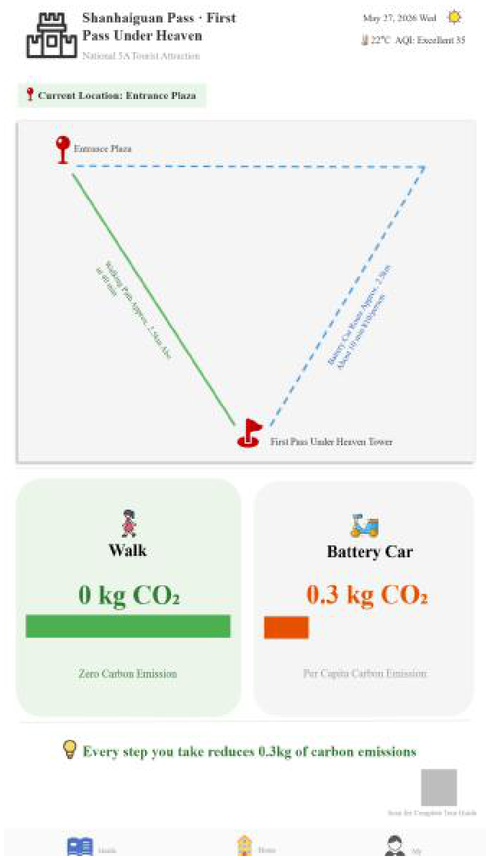

FIGURE 1. Interface prototype for Decision Point A (Entrance Plaza) using the data-driven strategy.

TABLE 4. User test procedure

Step	Content	Duration
1. Instruction	The experimenter briefly introduced the purpose of the test (without revealing the research hypotheses) and guided the participants on how to complete the questionnaire.	2 min
2. Pre-questionnaire	Participants filled in their demographic information (gender, age).	2 min
3. Interface viewing and evaluation	Six interfaces were displayed in random order, each viewed for 20–30 seconds.	6 min
4. Behavioral intention rating	After viewing each interface, participants answered: "How likely would you be to choose the recommended low-carbon travel option?" (1 = very unlikely, 7 = very likely).	5 min
5. Preference ranking	After viewing all six interfaces, participants selected the top two interfaces that "most made them want to choose a low-carbon travel option."	2 min

The total duration of a single test session was approximately 15–20 minutes.

This study obtained verbal informed consent from all participants. Prior to testing, participants were informed that:

(1) the research purpose was to "evaluate different styles of scenic spot wayfinding interface designs";

(2) participation was completely voluntary and they could withdraw at any time;

(3) the data would be used solely for academic research in an anonymised manner;

(4) participation or non-participation would not affect any course grades. The questionnaire did not collect any personally identifiable information such as names or student ID numbers, thereby ensuring anonymity.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

A. PARTICIPANT DEMOGRAPHICS

A total of 32 valid questionnaires were collected in this test. The participant demographic information is as follows:

TABLE 5. User test procedure

Variable	Category	n	%
Gender	Male	13	40.6
Gender	Female	19	59.4
Age	18–22 years	21	65.6
Age	23–26 years	1	3.1
Age	27–30 years	4	12.5
Age	31–40 years	2	6.3
Age	41–50 years	2	6.3
Age	51–60 years	2	6.3

B. EFFECTS OF DIFFERENT STRATEGIES ON LOW-CARBON BEHAVIOURAL INTENTION

The descriptive statistical results for low-carbon behavioural intention under the three strategy conditions are as follows:

TABLE 6. Descriptive statistics of behavioral intentions across three strategies

Strategy type	M	SD	Min	Max
Strategy A: Data-driven	4.75	1.68	1	7
Strategy B: Emotion-driven	4.80	1.49	1	7
Strategy C: Social norm-driven	4.78	1.62	1	7

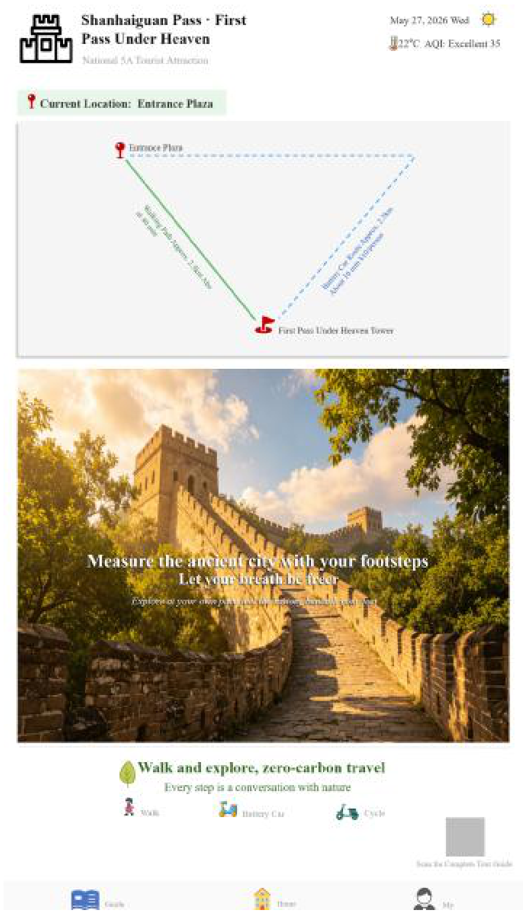

FIGURE 2. Interface prototype for Decision Point A (Entrance Plaza) using the emotion-driven strategy.

Note. Behavioral intention was measured on a 7-point Likert scale (1 = very unlikely, 7 = very likely).

As can be seen from the means, the behavioural intention scores for the three strategies were very close, with the emotion-driven strategy being slightly higher ($M = 4.80$), followed by the social norm-driven strategy ($M = 4.78$), and the data-driven strategy being slightly lower ($M = 4.75$), yielding a range of only 0.05.

Taking visual guidance strategy type as the independent variable and low-carbon behavioural intention as the dependent variable, a repeated measures ANOVA was conducted.

TABLE 7. Results of repeated measures ANOVA

Effect	SS	df	MS	F	p	η^2
Strategy	0.08	2	0.04	0.02	.98	.001
Error (Strategy)	118.9	62	1.92			

Note. η^2 = partial eta squared. Mauchly's test of sphericity indicated that the assumption of sphericity was met ($W = .93$, $p = .33$). The main effect of strategy type was not significant, $F(2, 62) = 0.02$, $p = .98$, $\eta^2 = .001$.

The ANOVA results indicated that the main effect of visual guidance strategy type on low-carbon behavioural intention was not significant. The three strategies yielded similar effects in promoting low-carbon behavioural intention under the present experimental conditions. As the main effect was not significant, post-hoc pairwise comparisons were not conducted.

It is noteworthy that the means for all three strategies were above the neutral point of 4 on the 7-point scale (4.75–4.80), preliminarily suggesting that embedding low-carbon behaviour guidance information in digital wayfinding systems can evoke moderately positive low-carbon behavioural intentions in tourists, regardless of the specific visual design strategy employed [50], [51]. This finding offers foundational support for the feasibility of low-carbon design in scenic spots and is consistent with existing research demonstrating that visual persuasion can effectively promote pro-environmental behaviour [16], [22]. The proper resolution of your figures will depend on the type of figure it is as defined in the "Types of Figures" section. Author photographs, color, and grayscale figures should be at least 300 dpi. Line art, including tables should be a minimum of 600 dpi.

A comparison of the present findings with those of Mundaca et al. (2022) reveals an interesting pattern: both studies found that social norm-based interventions produced limited effects on low-carbon mobility intentions. While

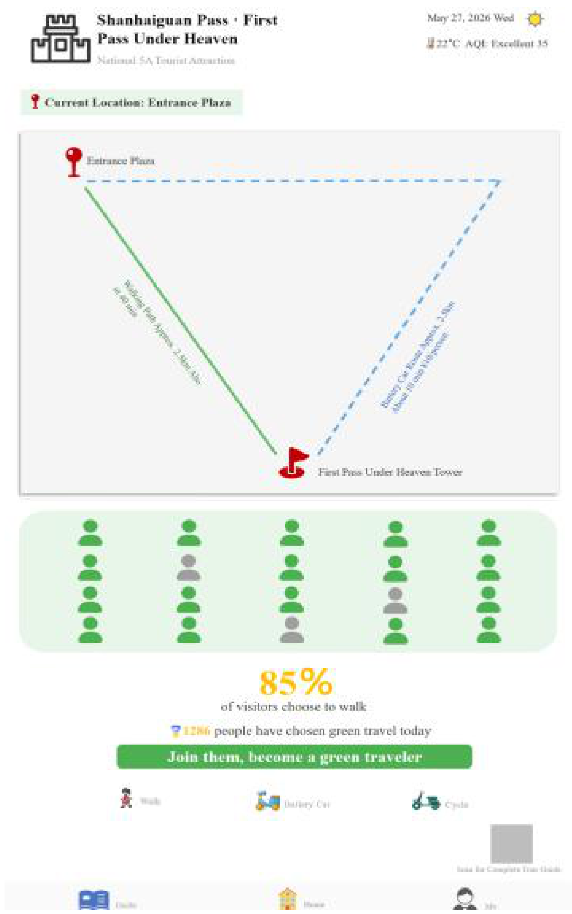

FIGURE 3. Interface prototype for Decision Point A (Entrance Plaza) using the social norm-driven strategy.

Mundaca et al. (2022) reported a marginally significant positive effect of injunctive norms on car-sharing adoption ($N = 720$; $N = 730$), the present study found a non-significant effect of social norm-driven visual strategies on walking/cycling intentions ($N = 32$). This convergence across different sample sizes, cultural contexts (Sweden vs. China), and low-carbon mobility options (car-sharing vs. active travel) suggests that social norm-based visual interventions may have relatively weak or context-dependent effects in tourism and transport settings. One plausible explanation is that low-carbon travel choices in leisure contexts are influenced more strongly by experiential factors (e.g., enjoyment, scenery, comfort) than by social pressure–a possibility further supported by the clear advantage of the emotion-driven strategy in the preference ranking [44], [52]. This finding underscores the importance of carefully considering the boundary conditions of social norm influence when designing behaviour change interventions in hedonic or leisure-oriented settings.

C. STRATEGY PREFERENCE RANKING

Participants selected the top two interfaces that "most made them want to choose a low-carbon travel option" from the six interfaces. The statistical results are as follows:

TABLE 8. Strategy preference ranking

Strategy type	Frequency	%
Strategy A: Data-driven	10	15.6
Strategy B: Emotion-driven	30	46.9
Strategy C: Social norm-driven	11	17.2
Total	51	79.7

Note. Of the 32 participants who completed this item, some selected only one preferred interface; thus, the total frequency (51) is lower than the theoretical maximum ($32 \times 2 = 64$). Strategy A = Data-driven strategy; Strategy B = Emotion-driven strategy; Strategy C = Social norm-driven strategy.

From the preference distribution, the emotion-driven interfaces were selected far more frequently (30 selections, 46.9%) than both the social norm-driven (11 selections, 17.2%) and data-driven (10 selections, 15.6%) interfaces. This contrast merits further discussion: although the three strategies did not show statistically significant differences in immediate behavioural intention ratings, at the level of preference choice, participants clearly leaned towards the emotion-driven visual design [44]. This result suggests that the effects of visual strategies may involve different mechanisms for behavioural intention and preference judgement–in immediate decision-making scenarios, the three strate-

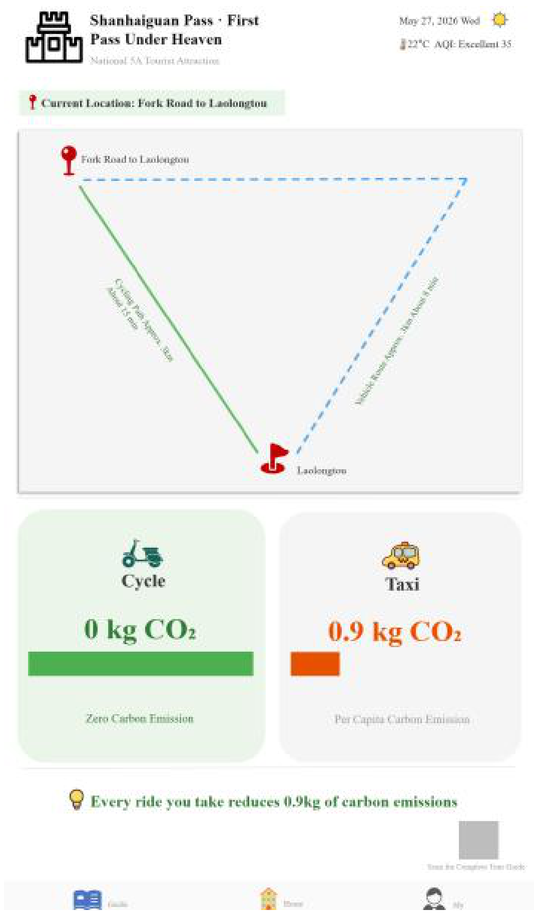

FIGURE 4. Interface prototype for Decision Point B (Fork Road to Laolongtou) using the data-driven strategy.

gies perform comparably; whereas in judgements involving aesthetic preference and emotional identification, emotion-driven design may hold an advantage. Prior research has also indicated that emotional factors play an important role in pro-environmental behavioural decision-making [52], [53].

V. CONSTRUCTION OF LOW-CARBON BEHAVIOUR VISUAL GUIDANCE STRATEGIES

A. STRATEGY CONSTRUCTION PRINCIPLES

Based on the experimental results and theoretical analysis presented in Chapter 4, this study distils three core principles:

Principle 1: Information Visualisation–Making Carbon Emissions "Visible"

The experimental results showed that the data-driven strategy yielded a mean behavioural intention score of 4.75, comparable to the other two strategies. Transforming abstract carbon emission data into intuitive visual forms can effectively reduce tourists' cognitive load [22], [43]. In design practice, the use of comparison charts and numerical card formats is recommended, with green representing low-carbon and grey/orange representing high-carbon to form a clear visual contrast.

Principle 2: Emotional Evocation–Touching Hearts with Beauty

The experimental results showed that the emotion-driven strategy not only achieved the highest mean behavioural intention score ($M = 4.80$) but also demonstrated a clear advantage in the preference ranking (46.9%) [44]. This finding corroborates the assertion regarding the "emotional evocation" function of images in visual persuasion theory [16] and further suggests that emotion-driven design may hold unique value in building user preference and brand affinity. In design practice, it is recommended to prioritise high-aesthetic-quality natural landscape photography or illustration, paired with a warm, soft natural colour palette and concise, evocative copy.

Principle 3: Social Norm Cueing–Making "Conformity" a Facilitator

The experimental results showed that the social norm-driven strategy ($M = 4.78$) performed comparably to the other two strategies [25], [45]. When individuals perceive a certain behaviour as "the choice of the majority," they are more likely to adopt that behaviour [21], [54]. In design practice, it is recommended to regularly or real-time update data on the number of visitors choosing low-carbon travel,

FIGURE 5. Interface prototype for Decision Point B (Fork Road to Laolongtou) using the emotion-driven strategy.

intuitively presenting social norm signals through crowd icon arrays and percentage figures.

B. STRATEGY SYSTEM CONSTRUCTION

Based on the above principles and empirical findings, this study proposes a "stratified adaptation" low-carbon behaviour visual guidance strategy system. In light of the preference data, the emotion-driven strategy is recommended for priority consideration across all levels, while retaining flexibility for the combined use of all three strategies:

TABLE 9. Stratified adaptation strategy system for low-carbon behavior visual guidance

Strategy level	Applicable scenario	Key design points	Recommended strategy combination
High-intervention level	Core scenic spot entrances, major transportation hubs	Place low-carbon guidance information at the visual centre; use strong colour contrast	Prioritise the emotion-driven strategy, supplemented by data-driven or social norm-driven elements
Medium-intervention level	Route forks between attractions, transportation transfer points	Balance navigation functions with low-carbon guidance information; flexibly adjust information density	Flexibly combine data-driven and emotion-driven strategies
Low-intervention level	General tour paths, rest areas	Unified green icons or low-carbon certification labels	Primarily lightweight prompts; avoid information overload

Note. In light of the emotion-driven strategy's advantage in the preference ranking (46.9%), it is recommended for priority consideration across all levels, while retaining flexibility for the combined use of all three strategies.

C. DESIGN SPECIFICATION RECOMMENDATIONS

1) Graphics and Icons

Low-carbon behaviour guidance information should adopt a unified green circular icon, with a size of no less than 5%–8% of the interface area [55]. Carbon emission comparison charts are recommended to adopt a side-by-side comparison layout [22]. Crowd icon arrays are recommended to have 5–8 avatars per row, with 3–5 rows.

2) Colour Scheme

Low-carbon options should uniformly use the green colour system, and high-carbon options should use the grey colour system [56]. Emotion-driven guidance interfaces are recommended to adopt a soft natural colour palette of warm green–goose yellow–sky blue–off-white. Social norm-driven interfaces are recommended to pair gold as an accent colour on a green primary background.

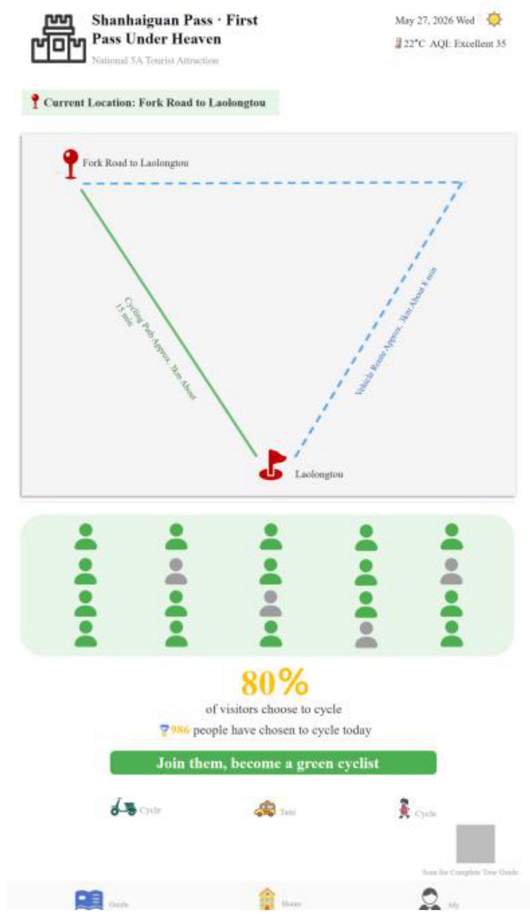

FIGURE 6. Interface prototype for Decision Point B (Fork Road to Laolongtou) using the social norm-driven strategy.

3) Information Hierarchy

The information hierarchy of the wayfinding interface is recommended as follows: the first level is navigation guidance information, the second level is low-carbon behaviour guidance information, and the third level is cultural display and service information. The low-carbon guidance information module is recommended to occupy 15%–25% of the interface area [57].

4) Dynamic Updates

It is recommended that scenic spots establish a regular update mechanism for low-carbon behaviour data. Social norm data should be updated daily, or real-time interfaced with the scenic spot's ticketing system data, with the update time and data source annotated to enhance information credibility [58].

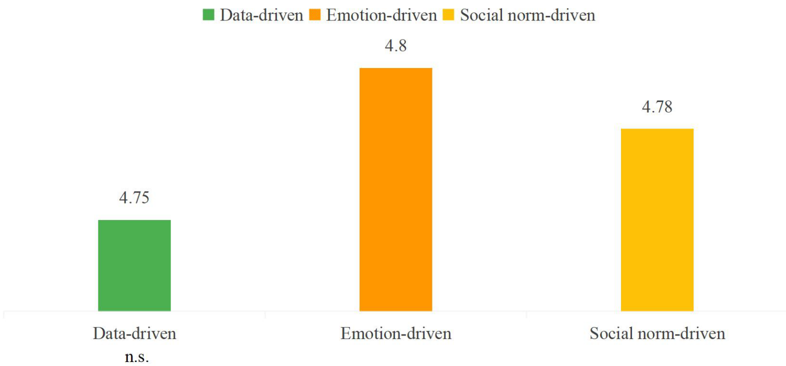

FIGURE 7. Comparison of mean behavioral intention scores across the three visual guidance strategies.

VI. CONCLUSION

A. RESEARCH SUMMARY

Taking Shanhaiguan Scenic Spot in Qinhuangdao as a case study, this research systematically investigated the core question of "how visual design strategies in smart scenic spot digital wayfinding systems can effectively guide tourists' low-carbon behaviour." The main conclusions are as follows:

First, integrating visual persuasion theory and persuasive design theory, a three-dimensional visual guidance framework of "information content – visual form – interaction mode" was constructed, providing a theoretical analysis tool for the low-carbon behaviour guidance design of digital wayfinding systems.

Second, user testing of three visual guidance strategies was designed and implemented. The experimental results indicated that while the three strategies did not show statistically significant differences in immediate behavioural intention scores ($F(2, 62) = 0.02$, $p = .98$), all three yielded means above the neutral point of 4 on the 7-point scale (4.75–4.80), preliminarily suggesting that visual guidance in itself is an effective low-carbon behaviour intervention tool [29], [30]. Furthermore, the emotion-driven strategy demonstrated a clear advantage in the preference ranking (46.9%), suggesting the possible existence of different mechanisms for behavioural intention and preference judgement [44]. Comparative analysis with existing literature further suggested that social norm-based visual interventions may have relatively weak or context-dependent effects in leisure-oriented settings, underscoring the importance of experiential and emotional factors in low-carbon travel choices [45].

Third, based on the empirical findings, a "stratified adaptation" low-carbon behaviour visual guidance strategy system was proposed, recommending priority consideration of the emotion-driven strategy while retaining flexibility for the combined use of all three strategies, thereby providing evidence-based decision-making support for low-carbon design in scenic spots.

B. THEORETICAL CONTRIBUTIONS

This study makes three primary theoretical contributions:

First, to the best of the author's knowledge, this study is among the first to systematically apply visual persuasion theory to low-carbon behaviour guidance research in scenic spot digital wayfinding systems [16], [27], thereby extending the application boundary of the theory to digital media in public spaces.

Second, by integrating visual persuasion theory and persuasive design theory [18], [31], a three-dimensional analytical framework of "information content – visual form – interaction mode" was constructed, addressing the deficiency of theoretical integration in existing research.

Third, through experimentation, a divergence between behavioural intention ratings and preference rankings was identified, providing new empirical evidence and a theoretical perspective for understanding the possible dual-pathway effects (immediate decision-making vs. long-term preference) of visual strategies [44], [52]. The comparative analysis with Mundaca et al. (2022) further contributes to the understanding of boundary conditions for social norm-based interventions in hedonic or leisure-oriented contexts [45].

This study provides empirically based design strategy recommendations for scenic spot managers, wayfinding system design enterprises, and cultural tourism authorities. Scenic spot managers can, according to the "stratified adaptation" system, prioritise the adoption of emotion-driven visual strategies and deploy differentiated low-carbon guidance designs at various visitor flow nodes [59]. Wayfinding system design enterprises can incorporate low-carbon behaviour guidance functions into the standardised design process of digital wayfinding products. Cultural tourism authorities can include low-carbon wayfinding system construction within the evaluation indicators for smart scenic spots and green scenic spots, thereby promoting the low-carbon development of tourism.

C. RESEARCH LIMITATIONS AND FUTURE DIRECTIONS

Research Limitations

1) Sample Limitations

The participants in this study constituted a convenience sample, predominantly university students aged 18–22 (65.6%), and differences may exist compared to actual scenic spot tourists in terms of age, educational background, and travel motivations [48]. Caution should be exercised when generalising the conclusions to a broader, more heterogeneous tourist population.

2) Scenario and Material Limitations

The experiment employed static images to simulate digital wayfinding screens, lacking authentic touch interaction and the scenic spot environmental atmosphere, which may have affected participants' sense of presence and the intensity of their behavioural intentions [49].

3) Measurement Limitations

The dependent variable was behavioural intention rather than actual behaviour, and an "intention–behaviour gap" exists [60]. Additionally, the preference ranking item was not set as a mandatory question; some participants selected only one preferred interface, resulting in the total frequency (51) falling below the theoretical maximum (64), which may have affected the completeness of the preference analysis.

4) Effect Size Limitations

The effect size of strategy type on behavioural intention in this study was extremely small ($\eta^2 = .001$), indicating that, with other variables controlled, strategy type per se had very limited explanatory power for behavioural intention. Future research could further explore the moderating effects of individual difference variables–such as personal values, environmental attitudes, and travel habits–on strategy effectiveness [37], [48].

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