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Examining Supply-Demand Coordination Mechanism and Consumer Satisfaction in Cultural Tourism from a Service Perspective

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Abstract. The cultural tourism industry faces significant challenges due to supply-demand imbalance, which severely restricts resource efficiency and erodes consumer satisfaction. To address this dilemma, this study adopts a Service Science perspective, introducing and constructing "Scientific Service" as a multi-dimensional construct (encompassing operational predictability, information accuracy, process efficiency, and experiential interactivity). The aim is to explore its intrinsic mechanism for enhancing consumer satisfaction. This research develops a chain model with (consumer-perceived) "supply-demand coordination" as a mediating variable. Structural Equation Modeling (SEM) analysis was conducted on empirical data from 485 visitors to national first-class museums and 5A-rated cultural ancient towns. The results indicate that Scientific Service significantly improves (perceived) supply-demand coordination and consumer satisfaction; supply-demand coordination is a crucial antecedent for enhancing consumer satisfaction; and "supply-demand coordination" plays a significant partial mediating role between Scientific Service and consumer satisfaction. The findings of this study reveal the mechanism by which "Scientific Service" enhances satisfaction, confirming that technology empowerment must optimize the fundamental management issue of "supply-demand coordination" to be efficiently transformed into perceived value for tourists.

Keywords: Scientific Service, Cultural Tourism, Supply-Demand Coordination, Consumer Satisfaction

1. Introduction

Cultural tourism is a form of tourism focused on exploring and experiencing the unique cultural elements of a destination. According to DATA BRIDGE statistics, the global cultural tourism market was valued at $7.25 billion in 2024 and is projected to reach $16.95 billion by 2032. As a product of the integration of the cultural and tourism industries, cultural tourism has entered a fast lane of rapid development (Zhang & Guo, 2022). Cultural tourism is not only a new driving force for high-quality economic development but also a vehicle for cultural heritage and value dissemination. However, alongside the booming development of cultural tourism, the structural imbalance between its supply and demand is becoming increasingly prominent.

The mismatch between cultural tourism supply and demand manifests in practice as follows: First, extremely uneven spatiotemporal distribution of visitor flows leads to both overloaded capacity and "congestion costs" for visitor experience at popular venues (such as museums, famous former residences) during peak seasons, while resources at off-peak times or some "unpopular" cultural attractions remain idle (Panzera, 2021). Second, the homogenization of supply structures and a "one-size-fits-all" model struggle to meet consumers' increasingly personalized, in-depth, and contextualized cultural experience demands (Chen et al., 2023). Third, information asymmetry leads to a failure in demand guidance, making it difficult for tourists to efficiently discover and access cultural tourism products that match their preferences. Persistent supply-demand imbalance not only restricts the resource allocation efficiency and sustainable development of the cultural tourism industry but also erodes consumers' perceived service quality, leading to a bottleneck in improving consumer satisfaction. In an era where "experience is king," how to effectively solve the problem of cultural tourism supply-demand coordination has become a major challenge for both industry managers and academia.

Facing the current challenges, the traditional tourism management paradigm, which relies on empirical judgment and ex-post adjustments, has proven inadequate. With the development and penetration of information technologies such as big data, AI, and 5G, service models are undergoing transformation (Ostrom et al., 2021). In this context, the concept of "Scientific Service," rooted in Service Science, management science, and information science, provides a new analytical framework for solving the aforementioned problems (Fu et al., 2023).

"Scientific Service" is not synonymous with traditional Service Quality (Parasuraman et al., 1988) or generalized "Smart Tourism." This study defines it as a service paradigm that relies on data-driven approaches, utilizes scientific models, and is supported by information technology. Its core characteristic lies in achieving precise insights, predictive management, and dynamic optimization of service supply and consumer demand through data collection and intelligent analysis across the entire service process (pre-service, in-service, post-service).

Specifically in the cultural tourism sector, scientific services play a role through the following avenues: 1) Precision in demand forecasting: Utilizing historical visitor data and machine learning algorithms to accurately predict future demand distribution, providing a basis for decision-making in crowd management and dynamic pricing; 2) Intelligent resource allocation: Based on real-time visitor monitoring, dynamically allocating service personnel, opening hours, and spatial capacity to achieve optimal resource configuration; 3) Personalized informationpush: Building user profiles to precisely push cultural content or tour routes that visitors may be interested in via smart terminals, guiding demand diversion; 4) Interactive and immersive experiences: Applying AR/VR and other technologies to recreate historical scenes, enriching the dimensions of cultural experience.

Evidently, the essence of scientific services is to fundamentally enhance the efficiency and accuracy of supply-demand matching through technological empowerment and process reengineering. This provides us with a crucial entry point: scientific services may be the core driving force for achieving supply-demand coordination in cultural tourism and, consequently, improving consumer

satisfaction.

Although a large body of literature has separately discussed the optimization of cultural tourism supply (Zhao et al., 2023), demand behavior (Lim et al., 2023), and the positive role of smart technology on tourist experience (Sustacha et al., 2023), a significant research gap still exists:

Existing research lacks a systematic empirical investigation into the internal mechanisms of how "scientific service" as a management paradigm affects consumer satisfaction. Specifically, does "scientific service" address the core pain point of supply-demand imbalance, and if so, how? Does the improvement in "supply-demand coordination" play a crucial mediating role between scientific service and consumer satisfaction? The "black box" of this pathway remains to be opened.

To bridge this gap, this study aims to construct and empirically test a theoretical model of "scientific services—supply-demand coordination—consumer satisfaction." Specifically, this study attempts to answer the following three core questions:

What direct impact do scientific services (and their different dimensions) in the cultural tourism field have on consumer satisfaction?

Can scientific services significantly improve consumers' perceived level of supply-demand coordination (such as temporal coordination, spatial coordination, content matching, etc.)?

Does supply-demand coordination play a mediating role between scientific services and consumer satisfaction? What are the nature and strength of its mechanism?

2. Literature Review

2.1.Research on the Supply and Demand Relationship in Cultural Tourism

Cultural tourism, as a product of the deep integration of the cultural and tourism industries (Richards, 2018), has become a significant growth pole in the global tourism market. Its core characteristic is that tourists are no longer satisfied with superficial sightseeing but seek in-depth exploration and experience of the destination's unique cultural elements, exhibiting typical "experience economy" and "service economy" features (Pine & Gilmore, 2021). However, with the vigorous development of the industry, the structural imbalance between supply and demand has become increasingly prominent. Scholars' research generally points to several core pain points: first, the extreme unevenness of tourist flow distribution in time and space leads to both "crowding damage" in popular venues and the idleness of less popular resources (Lin et al., 2024); second, the widespread homogeneity and "one-size-fits-all" model on the supply side make it difficult to match consumers' increasingly personalized and contextualized demands for in-depth experiences (Binkhorst & Den Dekker, 2013); finally, information asymmetry between supply and demand makes it difficult for tourists to efficiently discover products that match their preferences, leading to a failure in demand guidance.

Facing the aforementioned challenges, the traditional tourism management paradigm, which relies on empirical judgment and ex-post adjustments, has proven inadequate. This passive management model struggles to achieve effective resource allocation and guarantee service quality in the face of highly dynamic and concurrent tourist demands (Buhalis et al., 2023). Persistent supply-demand mismatch will ultimately erode consumer satisfaction and constrain the sustainable development of the industry.

2.2.Research on Consumer Satisfaction

Consumer satisfaction is a core issue in the field of service management. Academia generally defines it using the "expectation-perception" theory, meaning satisfaction is the cognitive and emotional evaluation consumers form after an experience by comparing their perceived performance with their prior expectations (Kark et al., 2022). In the context of tourism, scholars have identified multiple antecedent variables. The traditional Service Quality (SERVQUAL) model emphasizes the importance of dimensions such as interpersonal interaction, reliability, and responsiveness in the service delivery

process (Parasuraman et al., 1988). However, with the increasing pressure from cultural tourism flows, structural factors stemming from supply-demand imbalance are receiving more attention. Specifically, tourists' perceived waiting time (Hui & Tse, 1996) and perceived crowding (Eroglu et al., 2022) have been proven to be major sources of negative emotions and low satisfaction ratings among tourists. Existing research reveals that high levels of temporal coordination (e.g., short waits) and spatial coordination (e.g., comfortable density) are core elements of tourists' perceived performance, directly influencing their expectation-perception comparison process, thereby determining the final level of satisfaction. Employing machine learning approaches (like GBDT combined with the SHAP interpretability framework) allows for more accurate prediction and explanation of the complex drivers and non-linear effects influencing tourist satisfaction in specific contexts such as film tourism (Tian et al., 2025).

2.3.Research on the Application of Scientific Service in Smart Tourism

To address the complex challenges in cultural tourism management, the application of information technology has spurred a wave of research into "Smart Tourism." Smart Tourism emphasizes the use of ICT, big data, IoT, and other technologies to achieve widespread interconnection of tourism information, intelligent resource management, and personalized tourist experiences (Gretzel et al., 2015). Research in this field has greatly promoted the application of technology in tourism scenarios, especially contributing significantly to enriching experience dimensions and improving information accessibility (Neuhofer et al., 2014). E-tourism quality (digital platform quality) significantly influences tourist revisit intention through the mediating roles of perceived value and tourist satisfaction, particularly in geographically constrained island destinations (Mendrofa et al., 2025). In the context of heritage tourism, digital transformation elements like social media marketing, along with destination image, positively influence the visitor experience, which in turn significantly predicts destination revisitation intention (Cuong et al., 2025). Digital transformation in the tourism industry has been empirically shown to positively impact sustainable growth by driving innovative change (Tran et al., 2025). However, the literature on Smart Tourism also has limitations; its discussions often focus on the realization of technological functions and "input-output" black-box discussions, relatively lacking a systematic management paradigm to guide how technology can fundamentally solve core operational problems such as supply-demand mismatch. Meanwhile, the concept of "Service Science," rooted in management science and information science, emphasizes treating service systems as a whole, using data-driven approaches, scientific models, and algorithms to achieve precise insights and dynamic optimization of the entire service process (Opazo-Basáez et al., 2022). Service Science provides methodological guidance for solving resource allocation problems in complex service systems, but its macro paradigm needs to be operationalized in specific industry contexts. Therefore, this study argues that neither "Smart Tourism" alone (focused on technological applications) nor "Service Science" alone (focused on management paradigms) is sufficient to encapsulate the systematic efforts of the cultural tourism industry to address supply-demand coordination issues.

The "Scientific Service" proposed in this study aims to integrate both: it is a service paradigm constructed with service science as its management core and smart technology as its means of implementation, designed to enhance operational efficiency and optimize tourist experiences. This construct is operationalized into four dimensions: "predictability of operational management" and "efficiency of service processes" reflect the core demands of service science for data insight and process optimization (Huang et al., 2020); while "precision of information services" and "interactivity of cultural experiences" stem from smart tourism's long-standing focus on situational awareness, personalizedpush, and immersive experiences (Ostrom et al., 2021). Corporate ESG (Environmental, Social, and Governance) practices, particularly environmental and governance factors, have a significant positive impact on consumer behavior, and this relationship is significantly moderated (amplified) by the firm's level of digital transformation (Paudel & Thapa, 2025). These four

dimensions collectively constitute the complete connotation of scientific service in the cultural tourism domain.

2.4.Related Research on Supply-Demand Coordination

In Service Operations Management, given the perishability, heterogeneity, and simultaneity of production and consumption inherent in services, supply-demand coordination has always been a core issue for ensuring service quality and operational efficiency. In the highly dynamic and crowd-intensive context of cultural tourism, scholars have begun to explore coordination mechanisms through different technical approaches. For example, the application of crowd prediction models and real-time monitoring systems (corresponding to "operational predictability" in this study) has been proven to effectively smooth demand peaks, alleviate tourists' perceived crowding, and thus enhance "spatial coordination" (Guo et al., 2019). Similarly, online time-slot booking and virtual queuing systems (corresponding to "process efficiency") have significantly improved tourists' perceived waiting times by optimizing service processes and managing tourist expectations, achieving "temporal coordination" (Hui & Tse, 1996). Furthermore, personalized information systems based on context awareness (corresponding to "information accuracy"), through precisepush, can not only guide demand diversion but also match supply with tourists' personalized preferences, addressing the issue of "content coordination" (Gretzel et al., 2015). Research focusing on a specific user group (international students) has led to the design of a platform combining shared bicycles with intelligent route planning and cultural exploration features to optimize user experience and promote cultural integration (Chen et al., 2024). Innovative digital tools like gamification and localized digital currencies can incentivize sustainable behaviors among urban tourists, coordinating tourism demand with environmental goals (Godbole et al., 2025).

2.5.Literature Review

In summary, existing literature reveals that the imbalance between supply and demand in cultural tourism is a management pain point, and "supply-demand coordination" is a critical process affecting consumer satisfaction. To address this challenge, academia has shifted from exploring technological applications in "smart tourism" to a management paradigm of "service science." Building on this, this study extracts the construct of "scientific service."

Nevertheless, the current research gap lies in the fact that, at a theoretical level, existing research lacks a systematic empirical examination of the internal mechanisms by which "scientific service" as a management paradigm influences consumer satisfaction; at a mechanistic level, how "scientific service" addresses the pain points of supply-demand imbalance, and whether "supply-demand coordination" plays a critical mediating role between scientific service and consumer satisfaction, the "black box" of this causal path remains to be opened. Therefore, to bridge this gap, this study aims to construct and empirically test a "scientific service — supply-demand coordination — consumer satisfaction" chain-like theoretical model, exploring whether and how scientific service enhances consumers' ultimate satisfaction evaluation by improving their perceived level of supply-demand coordination.

3. Theoretical Model and Research Hypotheses

3.1.Definition of Core Variables

3.1.1. Scientific Service

"Scientific service" is the starting point and core explanatory variable of this study. Unlike the traditional service quality (SERVQUAL) model, which focuses on "five dimensions" (reliability, responsiveness, etc.) (Parasuraman et al., 1988), "scientific service" in this study is a multi-dimensional construct, specifically referring to a service paradigm in the cultural tourism domain where managers (suppliers) utilize data, algorithms, and intelligent technologies to improve

operational efficiency and optimize tourist experience (Fu et al., 2023). Combining relevant literature on service science and smart tourism (Gretzel et al., 2015; Huang et al., 2020), this study operationalizes it into four key dimensions:

Operational Proactiveness: Refers to the ability to scientifically predict future tourist demand using big data analytics (e.g., historical visitor flow, real-time monitoring, external event data) and proactively deploy resources and management plans (e.g., dynamic visitor flow guidance, flexible capacity management).

Information Precision: Refers to highly personalized, relevant, and timely information push and decision support services provided through smart terminals (e.g., APP, mini-programs), based on tourist profiles and situational awareness (e.g., location, time, preferences).

Process Efficiency: Refers to the ability to simplify service delivery processes using digital technologies (e.g., online reservations, smart ticketing, virtual queuing, rapid response systems) and reduce non-value-added time for tourists (e.g., queuing, waiting, searching).

Experiential Interactivity: Refers to the application of technologies such as AR, VR, and 5G to transform static cultural resources into dynamic, immersive, and interactive experiential products, thereby enriching visitors' perceptions and deepening their understanding of culture.

3.1.2. Supply-Demand Coordination

"Supply-demand coordination" is the core mediating mechanism of this study. This study does not measure from the perspective of macro resource allocation efficiency (e.g., bed utilization rate), but rather follows the service-dominant logic (S-D Logic) and measures from the perspective of consumer perception (Vargo & Lusch, 2004). "Perceived supply-demand coordination" is defined as tourists' subjective evaluation of the degree of fit between their individual needs (time, space, content) and the actual supply of the service system (resource availability, matching degree) during the service encounter. This study operationalizes it into three dimensions:

Perceived Temporal Coordination: Tourists' perception of the reasonableness and acceptability of the time spent in the service process (e.g., entering the park, waiting for attractions, dining), reflecting the match between the speed of service supply and tourists' time demands.

Perceived Spatial Coordination: Tourists' perception of the crowding level in the touring environment (e.g., core exhibition areas, main passages, public facilities), reflecting the match between physical space capacity and instantaneous visitor flow demand.

Perceived Content Coordination: Tourists' perception of the match between the cultural tourism products, information, and services they receive and their pre-trip expectations, personalized preferences, and situational needs.

3.1.3. Consumer Satisfaction

"Consumer satisfaction" is the ultimate outcome variable in this study. This study adopts the classic "Expectation-Perception" theory (Oliver, 1980), defining consumer satisfaction as the overall cognitive and emotional evaluation (Fornell, 1992) that tourists form after experiencing cultural tourism services, by comparing their perceived performance with their prior expectations. It is a comprehensive indicator that reflects tourists' overall evaluation of their cultural tourism experience.

3.2.Theoretical Model

Based on the variable definitions above, this study constructs the theoretical model shown in Figure 1. This model hypothesizes that:

"Scientific Service" (IV), as an antecedent variable, not only directly impacts "Consumer Satisfaction" (DV).

"Scientific Service" (IV) also indirectly affects "Consumer Satisfaction" (DV) by enhancing the

level of "Perceived Supply-Demand Coordination" (MV).

Therefore, "supply-demand coordination" plays a mediating role between "scientific services" and "consumer satisfaction."

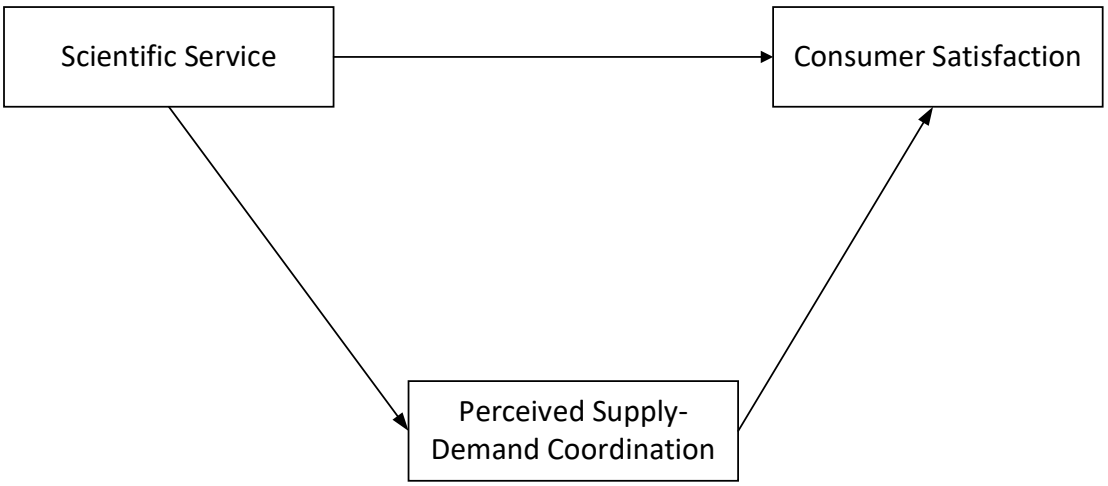

Fig.1: Theoretical Model

3.3.Research Hypotheses

3.3.1. Direct Relationship between Scientific Services and Consumer Satisfaction

Scientific services, through their multi-dimensional integrated functions, directly enhance tourists' perceived service quality and perceived value (Zeithaml, 1988). A service system that integrates operational predictability, information accuracy, process efficiency, and experiential interactivity can provide tourists with lower search costs, more convenient access to services, and richer emotional and cognitive experiences (Neuhofer et al., 2014). The "value-added" and "burden-reducing" effects brought about by technological empowerment go beyond traditional service encounters, directly impacting tourists' expectation-perception comparison process, thereby having a positive prior influence on overall satisfaction. Therefore, this study proposes:

H1: Scientific services have a significant positive impact on consumer satisfaction.

3.3.2. Relationship between Scientific Services and Supply-Demand Coordination

The core value of scientific services lies in their systematic optimization of the supply-demand matching mechanism (Fu et al., 2023). Traditional tourism management models often lag behind instantaneous changes in demand, while scientific services, with their data-driven and predictive capabilities, enable managers to actively intervene in resource allocation and demand distribution (Gretzel et al., 2015). Whether it is smoothing demand peaks over time through crowd flow prediction, guiding spatial distribution of crowd flow through precise push (push notifications), or improving the immediate response of service supply through intelligent processes, the ultimate goal is to enhance the matching degree between supply and demand in terms of time, space, and content dimensions. Therefore, the improvement of scientific service levels will directly translate into a higher level of supply-demand coordination perceptible to tourists.

H2: Scientific services have a significant positive impact on (consumer-perceived) supply-demand coordination.

3.3.3. Relationship between Supply-Demand Coordination and Consumer Satisfaction

According to expectation-perception theory (Oliver, 1980), tourist satisfaction depends on the gap between perceived performance and expectations. In the context of cultural tourism, "perceived supply-demand coordination" is a core element constituting tourists' perceived performance. High levels of temporal coordination (e.g., short waiting times), spatial coordination (e.g., comfortable

visitor density), and content coordination (e.g., recommendations that match preferences) directly meet tourists' basic expectations for smooth, comfortable, and personalized experiences (Hui & Tse, 1996). Conversely, perceived supply-demand imbalance (e.g., congestion, long queues) is the main source of negative emotions and low satisfaction ratings among tourists. Therefore, the level of supply-demand coordination is a key antecedent determining consumer satisfaction.

H3: (Consumer-perceived) supply-demand coordination has a significant positive impact on consumer satisfaction.

3.3.4. Mediating Role of Supply-Demand Coordination

Synthesizing the above logic, the core argument of this study is that the improvement of consumer satisfaction by scientific services is largely achieved by solving the fundamental problem of "supply-demand coordination." Scientific services (H2) provide the technical means and management paradigm for achieving coordination, while the achievement of coordination (H3) forms the core basis of a satisfactory tourist experience. If scientific services (such as a smart app) fail to effectively improve tourists' perceived spatiotemporal crowding or content mismatch (i.e., fail to achieve coordination), their direct contribution to satisfaction will be greatly reduced. Therefore, supply-demand coordination is a key transmission mechanism connecting scientific service input and consumer satisfaction output.

H4: Supply-demand coordination (as perceived by consumers) plays a mediating role between scientific services and consumer satisfaction.

4. Research Design

4.1.Questionnaire Design

This study employs a questionnaire survey to collect primary data. The questionnaire design strictly adheres to social science research paradigms and consists of two parts: the first part measures the core constructs of this study (scientific service, supply-demand coordination, and consumer satisfaction); the second part collects demographic information and behavioral characteristics of respondents (as control variables). Except for basic information, all measurement items use a 7-point Likert scale, ranging from "1 = strongly disagree" to "7 = strongly agree."

To ensure the content validity and reliability of the scales, the core variables in this study are based on established scales from authoritative domestic and international literature, adapted to the specific context of cultural tourism.

1. Scientific Service (IV) As "scientific service" is a new perspective introduced in this study, there is no unified, mature scale available. This study designs the scale from the perspective of tourist perception, based on the four-dimensional definition in Chapter 3, and drawing upon relevant literature on smart tourism service quality (Gretzel et al., 2015), the Technology Acceptance Model (TAM), and service science (Fu et al., 2023).

2. Perceived Supply-Demand Coordination (MV) This scale is based on the dimensional definitions in Chapter 3 and references relevant research on Perceived Crowding (Machleit et al., 1994) and Perceived Waiting Time.

3. Consumer Satisfaction (DV) This study adopts widely used and reliable scales in academia, primarily drawing from the research of Fornell (1992) and Oliver (1980).

4. Control Variables To exclude potential interference from other factors on consumer satisfaction, this study selected the following variables: gender, age, education level, monthly income, past visitation experience (e.g., first-time visit), accompanying group (e.g., alone, with family, with friends), and duration of the current visit.

4.2.Pre-survey and Questionnaire Revision

To ensure the clarity, readability, and accuracy of the measurement constructs in the questionnaire items, this study conducted a rigorous pre-testing process before the formal survey.

After the initial questionnaire was drafted, three professors in tourism management and two senior managers from smart cultural tourism enterprises were invited to evaluate it. The experts primarily provided feedback on the rationality of the dimensional division and the precision of the item wording for the "scientific service" and "supply-demand coordination" scales. For instance, one item related to "predictability of operational management" was changed from "...applied big data" to "...can scientifically predict passenger flow...", making it more focused on tourists' intuitive perception rather than technical judgment.

Following revisions based on expert feedback, 80 questionnaires were distributed for a small-sample test at a national first-class museum in May 2024. The purpose of this test was to check for any misunderstandings among respondents and to conduct a preliminary reliability analysis.

By analyzing the pre-test data, the internal consistency coefficient (Cronbach's α) was calculated for each scale. The results showed that the α coefficients for all constructs were above 0.75, indicating good preliminary reliability of the scales. Simultaneously, based on respondent feedback, individual obscurely worded items (e.g., "...granularity of service") were refined, leading to the final formal survey questionnaire.

4.3.Data Collection

4.3.1. Survey Subjects

The theoretical model of this study emphasizes the role of "scientific services." Therefore, the selection of data collection locations must be typical, meaning that these locations have deeply applied digital and intelligent technologies in their operational management. This study selected two national first-class museums in eastern and central China and one 5A-level smart cultural ancient town as survey locations.Bothlocations have implemented "scientific service" measures such as online time-slot reservations, intelligent visitor flow monitoring and guidance, AR/VR immersive experiences, and personalized information push, providing an ideal observation field for this study.

4.3.2. Sampling and Data Acquisition

To ensure sample diversity and representativeness, this study adopted a hybrid sampling method of "online supplementation + offline primary." Data collection took place from July to October 2024, covering the summer peak season, the "Golden Week" holiday in October, and off-peak periods, which helps capture tourist perceptions under different visitor densities.

Offline Data Collection: This was conducted using Systematic Random Sampling (every 5th departing tourist was invited every 10 minutes). To improve the response rate, tourists received a small souvenir after completing the questionnaire (primarily filled out online by scanning a QR code). A total of 450 questionnaires were distributed offline, with 403 valid questionnaires returned.

Online Data Collection: To supplement the geographical limitations of the offline sample, questionnaire links were targeted and distributed through travelogue communities on mainstream domestic online travel platforms (such as Ctrip and Mafengwo), inviting tourists who had visited the target scenic spots during the aforementioned period to complete them. A total of 176 questionnaires were collected online. After screening by IP address and completion time (excluding questionnaires completed in less than 120 seconds), 82 valid questionnaires were obtained.

4.3.3. Sample Overview

A total of 485 valid samples were obtained in this study. The basic characteristics of the samples are shown in Table 1.

Table 1. Basic Characteristics of Samples

Variable	Category	Frequency (N)	Percentage (%)
Gender	Male	219	45.2
	Female	266	54.8
Age	18 and under	31	6.4
	19–25	126	26.0
	26–35	185	38.1
	36–45	97	20.0
	46 and above	46	9.5
Education level	High school and below	44	9.1
	Junior college (associate)	98	20.2
	Bachelor's degree	247	50.9
	Master's degree and above	96	19.8
Monthly income (RMB)	5,000 and below	108	22.3
	5,001–10,000	191	39.4
	10,001–15,000	114	23.5
	15,001 and above	72	14.8
Visiting experience	First-time visit	318	65.6
	Multiple visits	167	34.4

The validity analysis of the sample (N=485) shows that the sample size exceeds 15 times the total number of measurement items, meeting the basic requirements for sample size in Structural Equation Modeling (SEM) analysis (Hair et al., 2010). The sample data indicates that the respondents are predominantly young and middle-aged (19-35 years old accounting for 64.1% of the total), with generally high levels of education (university undergraduate and above accounting for 70.7% of the total). According to relevant data from the "2024 China Cultural Tourism Development Report" released by the Data Center of the Ministry of Culture and Tourism, the core consumer group for cultural tourism in China currently exhibits significant characteristics of youthfulness and high education, with tourists aged 26-45 being the main force in the market. The sample distribution characteristics of this study are largely consistent with this macro trend, indicating that the sample data has good representativeness in key demographic dimensions, and the research conclusions have a solid basis for external inference.

5. Empirical Analysis and Results

This study used SPSS 26.0 and AMOS 24.0 statistical analysis software to process the collected data and test the model. The analysis process mainly included data cleaning and descriptive statistics, reliability and validity tests, common method bias tests, and hypothesis testing of the structural equation model.

5.1.Data Cleaning

A total of 626 questionnaires were collected through online and offline channels in this study. To ensure the authenticity and validity of the data, the raw data was first subjected to strict cleaning. Exclusion criteria included: 1) excessively short response times (e.g., total duration < 120 seconds); 2) a large number of regular responses (e.g., selecting the same option for all items); 3) a large number of missing values for key variables (core constructs). After the above screening procedures, 141 invalid questionnaires were excluded, and a final sample of 485 valid questionnaires was obtained, with an effective questionnaire recovery rate of 77.48%. This sample size (N=485) meets the

minimum sample size requirements for Structural Equation Modeling (SEM) analysis (Hair et al., 2010).

5.2.Reliability, Validity, and Common Method Bias Testing

5.2.1. Reliability Test

Cronbach's α coefficient was used to evaluate the internal consistency of each construct's scale.As shown in Table 5-2, for scientific services (SS, 4 dimensions, 12 items): α = 0.915; for supply-demand coordination (PSD, 3 dimensions, 9 items): α = 0.893; for consumer satisfaction (CS, 3 items): α = 0.928. All α coefficients were significantly higher than the recommended threshold of 0.70 (Nunnally, 1978), indicating high internal consistency and stability of the scales.

5.2.2. Validity Test

1. Content Validity

The scales used in this study are based on mature scales from authoritative domestic and international literature, adapted to the context of cultural tourism. During the questionnaire development process, multiple rounds of expert evaluation and pre-survey revisions were conducted to ensure that the items accurately and comprehensively reflect the intended constructs, thus demonstrating good content validity for this study.

2. Construct Validity

This study employs Confirmatory Factor Analysis (CFA) to examine the construct validity of the scales, including convergent validity and discriminant validity. First, a CFA analysis was performed on the measurement model containing all constructs. The model fit indices are shown in Table 2. All fit indices met the ideal standards (Hair et al., 2010), indicating a good fit between the measurement model and the observed data in this study.

Table 2. Model Fit Indices

Indicator	Value	Threshold
χ^2/df	2.185	< 3
GFI	0.922	> 0.90
CFI	0.958	> 0.90
TLI	0.951	> 0.90
RMSEA	0.049	< 0.08

3.Convergent Validity

This is assessed using three indicators: Standardized Factor Loadings (FL), Composite Reliability (CR), and Average Variance Extracted (AVE). As shown in Table 3.

(1) Factor Loadings (FL): The standardized factor loadings for all measurement items range from 0.760 to 0.905, all exceeding the recommended standard of 0.70.

(2) Composite Reliability (CR): The CR values for the three constructs were 0.917, 0.895, and 0.930, respectively, all exceeding the standard of 0.70.

(3) Average Variance Extracted (AVE): The AVE values for the three constructs were 0.689, 0.681, and 0.816, respectively, all exceeding the standard of 0.50.

The data indicate that all measurement items effectively reflect their respective latent variables, and the scale demonstrates excellent convergent validity.

Table 3. Reliability and Convergent Validity Results (N = 485)

Construct	Items	Factor Loadings (FL)	Cronbach's α	CR	AVE
Scientific Service (SS)	SS_OP1	0.805	0.915	0.917	0.689
	SS_OP2	0.812			
	SS_OP3	0.790			
	SS_IP1	0.841			
	SS_IP2	0.865			
	SS_IP3	0.833			
	SS_PE1	0.798			
	SS_PE2	0.811			
	SS_PE3	0.760			
	SS_EI1	0.850			
	SS_EI2	0.832			
	SS_EI3	0.847			
Perceived Supply–Demand Coordination (PSD)	PSD_TC1	0.799	0.893	0.895	0.681
	PSD_TC2	0.813			
	PSD_TC3	0.806			
	PSD_SC1	0.852			
	PSD_SC2	0.839			
	PSD_SC3	0.817			
	PSD_CC1	0.774			
	PSD_CC2	0.825			
	PSD_CC3	0.802			
Consumer Satisfaction (CS)	CS1	0.898	0.928	0.930	0.816
	CS2	0.905			
	CS3	0.891			

Note:SS_OP = Operational Predictiveness; SS_IP = Information Precision; SS_PE = Process Efficiency; SS_EI = Experiential Interaction. PSD_TC = Temporal Coordination; PSD_SC = Spatial Coordination; PSD_CC = Content Coordination.

4.Discriminant Validity

This study uses the Fornell & Larcker (1981) criterion to test for discriminant validity. This criterion requires that the square root of the AVE value for each construct must be greater than its correlation coefficients with all other constructs. As shown in Table 4, the bolded values on the diagonal are the $\sqrt{AVE}$ values for each construct, and the off-diagonal values are the Pearson correlation coefficients between constructs.

Table 4. Variable Means, Standard Deviations, and Discriminant Validity Test (N=485)

Construct	Mean	S.D.	1.SS	2.PSD	3.CS
1.Scientific Service(SS)	5.21	1.15	0.830		
2.Perceived Supply–Demand Coordination(PSD)	5.09	1.20	.689***	0.825	
3.Consumer Satisfaction(CS)	5.33	1.18	.612***	.745***	0.903

Note: *** indicates $p < 0.001$. Bold diagonal values are the square roots of AVE for each construct.

5.2.3. Common Method Bias Test

Since the independent, mediating, and dependent variable data in this study were all collected from the same respondents at the same time point using self-report methods, common method bias might exist. This study used Harman's single-factor test for diagnosis (Podsakoff et al., 2003). All measurement items were included in exploratory factor analysis (EFA). Without rotation, the first principal component (i.e., single factor) extracted explained 37.41% of the total variance. This value did not exceed the critical standard of 40%, indicating that the common method bias in this study is within an acceptable range, the data results are reliable, and will not seriously mislead subsequent hypothesis testing.

5.3.Hypothesis Testing

5.3.1. Structural Model Fit Test

This study first conducted an overall fit test on the structural model (shown in Figure 3-1) that included all latent variables. The model's fit index results are shown in Table 5-4. As can be seen from Table 5, all key fit indices of the structural model in this study met the recommended standards in academia. The χ^2/df was 2.315, which is less than 3.0; GFI and AGFI were both greater than 0.9; CFI and TLI were both greater than 0.95, reaching an ideal level; RMSEA was 0.048, which is less than 0.05. In summary, the theoretical model constructed in this study has a very ideal fit with the actual observed data, allowing for subsequent path analysis and hypothesis testing.

Table 5. Structural Model Fit Indices (N=485)

Fit Indices	Value	Recommended Criteria	Judgement
χ^2/df	2.315	< 3.0	Good
GFI	0.918	> 0.90	Good
AGFI	0.903	> 0.90	Good
NFI	0.945	> 0.90	Good
CFI	0.962	> 0.90 (ideal > 0.95)	Ideal
TLI	0.957	> 0.90	Ideal
RMSEA	0.048	< 0.08 (good < 0.05)	Good

5.3.2 Path Analysis and Hypothesis Testing

This study estimated the path coefficients in the structural model, and the results are shown in Table 6 and Figure 2.

Table 6. Path Coefficients and Hypothesis Testing Results

Hypothesis	Path	Standardized Coefficient (β)	S.E.	C.R. (t-value)	P-value (Sig.)	Result
H1	Scientific Service (SS) → Consumer Satisfaction (CS)	0.254	0.093	2.651	0.008	Supported
H2	Scientific Service (SS) → Perceived S–D Coordination (PSD)	0.701	0.078	10.235	***	Supported

H3	Perceived S–D Coordination (PSD) → Consumer Satisfaction (CS)	0.588	0.101	7.642	***	Supported

Note: *** indicates p < 0.001; ** indicates p < 0.01.

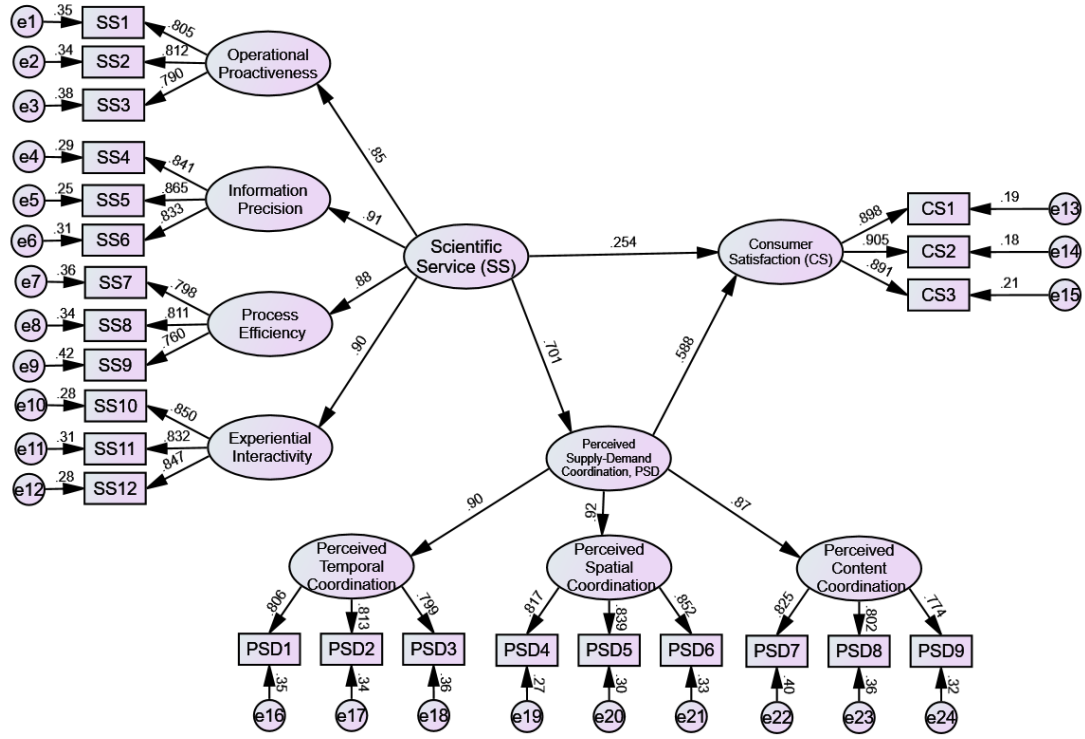

Fig 2: Structural Model

H1 Test: The standardized path coefficient of "scientific service" on "consumer satisfaction" is 0.254 (t=2.651, p=0.008<0.01). This path shows a significant positive effect, and Hypothesis H1 is supported.

H2 Test: The standardized path coefficient of "scientific service" on "(perceived) supply-demand coordination" is 0.701 (t=10.235, p<0.001). This path shows a highly significant positive effect, indicating that an improvement in scientific service levels can effectively enhance the perceived supply-demand coordination status of tourists. Hypothesis H2 is supported.

H3 Test: The standardized path coefficient of "(perceived) supply-demand coordination" on "consumer satisfaction" is 0.588 (t=7.642, p<0.001). This path shows a highly significant positive effect, indicating that the higher the perceived supply-demand coordination, the higher the consumer satisfaction. Hypothesis H3 is supported.

5.3.3. Mediation Effect Test

To test the mediating effect of "Supply-Demand Coordination" (PSD) between "Scientific Services" (SS) and "Consumer Satisfaction" (CS) (H4), this study employed the Bootstrap resampling method (Preacher & Hayes, 2008). This method does not require the assumption of a normal sampling distribution, leading to more robust test results. In this study, 5,000 repeated samples were set in AMOS, and 95% bias-corrected confidence intervals were calculated. The results of the mediation effect test are shown in Table 7.

Table 7: Mediation Effects via Bootstrap, N = 5000

Effect Type	Path	Standardized Coefficient (β)	95% CI	Result
Indirect Effect (H4)	SS → PSD → CS	0.412	[0.335, 0.498]	Significant
Direct Effect (H1)	SS → CS	0.254	[0.081, 0.427]	Significant
Total Effect	SS → CS (Total)	0.666	[0.579, 0.753]	Significant

The total effect of "scientific service" on "consumer satisfaction" is 0.666, and the 95% CI [0.579, 0.753] does not include 0, indicating that scientific service generally has a significant positive effect on satisfaction. The standardized coefficient of the indirect effect (i.e., mediating effect) of "supply-demand coordination" is 0.412 (i.e., H2 path 0.701 * H3 path 0.588). Its 95% bias-corrected confidence interval is [0.335, 0.498]. Since this interval does not contain 0, it indicates that the mediating effect is significant. Hypothesis H4 is strongly supported. While the mediating effect is significant, the direct effect of "scientific service" on "consumer satisfaction" (β =0.254$) also does not include 0 in the 95% CI [0.081, 0.427], indicating that the direct effect is also significant. When both the direct effect and the indirect effect are significant, it can be determined that "(perceived) supply-demand coordination" plays a partial mediating role between "scientific service" and "consumer satisfaction."

The indirect effect accounts for 61.9% of the total effect, indicating that 61.9% of the positive impact of scientific services on consumer satisfaction is achieved through the mediating path of "improving perceived supply-demand coordination."

6. Conclusions and Discussion

6.1.Research Conclusions

This study explored the internal mechanism by which scientific services enhance consumer satisfaction, and all research hypotheses were supported by the data:

1.Scientific services have a significant direct positive impact on consumer satisfaction (H1 supported). The study found that a scientific service system, centered on operational predictability, information accuracy, process efficiency, and experiential interactivity, can itself act as a high-level perception of service quality, directly enhancing tourists' overall satisfaction.

2.Scientific services have a significant positive impact on (consumer-perceived) supply-demand coordination (H2 supported). Data indicate that scientific services are a powerful driver for improving tourists' perceived coordination levels. The implementation of scientific services (β =0.701) can effectively alleviate perceived time conflicts (queues), spatial conflicts (crowding), and content mismatches (unmet personalized needs) among tourists.

3.(Consumer-perceived) supply-demand coordination has a significant positive impact on consumer satisfaction (H3 supported). Perceived supply-demand coordination is a core antecedent of satisfaction. High levels of perceived time, spatial, and content coordination (β =0.588) among tourists form a solid foundation for their highly satisfying experiences.

4.(Consumer-perceived) supply-demand coordination plays a significant partial mediating role between scientific services and consumer satisfaction (H4 supported). Bootstrap test results show that both the indirect effect (0.412) and the direct effect (0.254) are significant. This indicates that scientific services not only directly enhance satisfaction but, more crucially, exert their effect through the mediating path of "improving supply-demand coordination." Data show that as much as 61.9% of the total effect of scientific services on satisfaction is achieved through this mediating path.

6.2.Theoretical Implications

First, it addresses the mechanistic gap in "how smart tourism creates value." Previous research often remained at a "input-output" black box discussion of how smart technologies (such as AI, big data) affect satisfaction (Gretzel et al., 2015). This study opens this "black box" by introducing "scientific service" as a systemic construct and empirically examining the mediating role of "supply-demand coordination." The research confirms that technology does not directly equate to satisfaction; rather, it is efficiently transformed into perceived value for tourists by optimizing "supply-demand coordination," a fundamental management issue in the tourism industry.

Second, it expands the application boundaries of Service Science in cultural tourism management. This study operationalizes "scientific service" from a macroscopic theoretical paradigm into measurable multi-dimensional constructs (e.g., operational predictability, information accuracy) and verifies its effectiveness as an antecedent variable. This advances the discussion of service science from the level of "technological application" to the level of "management mechanisms," confirming that scientific service is an effective paradigm for solving resource mismatch problems in complex service systems (such as the cultural tourism industry).

Third, it provides a new path for improving satisfaction in the field of tourism management. Traditional satisfaction models highly focus on interpersonal interactions in service encounters (e.g., employee attitudes). This study reveals an equally important, and perhaps more fundamental, path: systematically re-engineering back-end operations and front-end experiences through "scientific service" to achieve "supply-demand coordination." In modern tourism, structural "coordination" issues (such as congestion, mismatch) have a more profound impact on satisfaction than occasional "attitude" issues.

6.3.Practical Implications

Based on the above conclusions, this study provides clear management implications for cultural tourism enterprises and government regulatory departments.

For cultural tourism enterprises, the implication of this study is the necessity of a strategic shift from "technology purchase" to "systematic investment." Enterprises should move beyond the limitations of a single APP or large screen, and instead build a data-centric closed-loop management system, especially strengthening the "predictive capability of operational management," shifting the management focus from "post-hoc remediation" to "pre-emptive prediction" and "in-process regulation." On this basis, all technological applications should be guided by the goal of "supply-demand coordination": utilizing intelligent scheduling systems to alleviate "time coordination" problems (e.g., virtual queuing), using real-time visitor flow monitoring and information guidance to resolve "spatial coordination" problems (e.g., congestion), and employing user profiling and LBS technology to address "content coordination" problems (e.g., personalized recommendations). Ultimately, through scientific services, "unpopular" cultural resources can be precisely activated, guiding demand from over-saturated core attractions to areas with potential, thereby achieving balanced utilization and maximized value of resources across the entire region.

For government and industry regulatory departments, their core responsibilities lie in "empowerment" and "integration." On the one hand, precise industrial policies should be introduced, and through special subsidies, technical training, and expert guidance, the threshold for small and medium-sized cultural tourism enterprises to "go digital, use data, and empower with intelligence" should be substantially lowered, promoting the overall popularization of the "scientific service" paradigm within the industry. On the other hand, the government should take the lead in breaking down "data silos" between individual enterprises, and spearhead the establishment of city-level or regional cultural tourism data centers. This will help achieve macro visitor flow regulation, emergency management, and precise marketing across different scenic spots, thereby realizing supply-demand coordination and high-quality development within the region on a larger scale.

6.4.Research Limitations and Future Outlook

Despite certain advancements, this study still has several limitations, which also point to directions for future research. Firstly, the sample source is limited, with data primarily concentrated in national museums and well-known ancient towns that already possess a high level of scientific service. Whether the research conclusions can be directly extended to small and medium-sized, less popular cultural tourism destinations in their nascent stages still requires further verification. Secondly, this study uses cross-sectional data to analyze the correlation between variables. Although causal logic was theoretically derived, it is unable to strictly establish causality from a temporal dimension. For example, tourist satisfaction might also inversely affect their perceived evaluation of coordination. Finally, the measurement dimensions of "scientific service" are limited. Although this study operationalized it into four dimensions, this may still not exhaust its full connotations in aspects such as "safety assurance" and "emergency response."

Addressing the above limitations, future research can be deepened in the following aspects: First, in terms of research methods, longitudinal studies or field experiments could be employed to enhance the validity of causal inference by comparing real changes before and after the introduction of a specific scientific service (e.g., a virtual queuing system). Second, in terms of research depth, one could delve from the overall construct into specific technologies, exploring the differentiated impact paths of various technologies (e.g., AI recommendation algorithms vs. VR immersive experiences) on the three sub-dimensions of supply-demand coordination (time, space, content), providing more refined decision-making bases for managers. Third, in terms of research breadth, moderating variables should be introduced to explore factors such as "input costs" and "technology privacy" concerns, to determine under what circumstances the positive effects of scientific services are strongest and their input-output ratio is highest.

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