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Evaluation of popular science tourism in Guangzhou HEMC based on PLS-SEM

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ABSTRACT

Science popularization is not only a prerequisite for national development, but also an effective means of enhancing citizens' personal quality. All sectors of society, represented by colleges and universities, bear the responsibility of promoting popular science. The integration of popular science and tourism in popular science tourism serves to advance both the field of popular science and the tourism industry simultaneously. The Guangzhou Higher Education Mega Center (HEMC) possesses abundant resources for science popularization and has the potential to develop popular science tourism, yet its current development in this area remains insufficient. This study utilizes Guangzhou HEMC as a case study and modifies the American Customer Satisfaction Index model by incorporating relevant questions pertaining to popular science tourism. A total of 280 valid questionnaires were collected through surveying, which were then analyzed to measure tourist satisfaction using the Tourist Satisfaction Index. The partial least squares structural equation model was employed for analysis, and on the basis of calculation results, the IPA map was constructed. The research revealed that tourists' satisfaction with popular science tourism at Guangzhou HEMC was suboptimal. Among the factors correlating to satisfaction, expectations, quality, and price are all important factors to consider when making a purchase decision; however, prioritizing expectations and quality can lead to greater satisfaction in the long run. Therefore, there is still ample room for improvement in the popular science tourism of HEMC Guangzhou. This can be achieved by intensifying publicity efforts, enhancing infrastructure, improving the quality and safety of catering services, strengthening the introduction and construction of popular science content, as well as appropriately reducing the price of popular science products and services.

1. Introduction

Science popularization tourism (hereinafter referred to as "popular science tourism"), which combines scientific education with travel, not only meets the requirements of national science popularization efforts but also promotes high-quality development in the tourism industry. Popular science tourism is generally considered a combination of science tourism and cultural tourism, with an emphasis on knowledge dissemination. It has become an important type of tourism. University towns, where universities and

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colleges are concentrated with abundant high-quality resources for promoting science, serve as ideal destinations for popular science tourism. Although popular science tourism has appeared in the academic world for a long time, there is still no unified opinion on its definition [1,2]. Early studies often suggest that its emergence and early development primarily occurred in developed countries and regions of Europe and America. The establishment of the German Museum in 1906 serves as a significant milestone marking its inception. In its initial stages, popular science tourism was predominantly focused on "industrial tourism", which aimed to showcase the industrial production processes to the public. For example, prominent activities included organized visits to production lines by renowned French automobile manufacturers such as Renault, Peugeot, and Citroen [1].

As early as 1990, geoscience-based tourism planning had already emerged in China. In the 21st century, China's rapid development of science and technology, social and economic progress has led to a growing demand for tourism experiences beyond mere sightseeing. Furthermore, with China placing greater emphasis on enhancing national scientific literacy, favorable conditions have been created for the growth of popular science tourism in the country. Around 2000, many destinations began to integrate tourism with science and culture, resulting in significant outcomes. During the same period, Beijing introduced several science and technology tourist attractions as well as specialized routes for popular science tourism. In Shanghai, numerous popular science tourism bases were constructed one after another, indicating that China's popular science tourism industry has started to take shape. The advancement of popular science tourism is intricately linked to the regional economy and scientific and technological advancements. During its initial stages, China's popular science tourism primarily flourished in large and medium-sized cities located in developed regions such as Beijing and Shanghai. Currently, venues and universities are experiencing a surge in popularity as a prominent type of popular science tourism. The feasibility and advantages of popular science tourism have been demonstrated through practical experience. Different regions in China have successfully utilized local popular science resources to implement various forms of popular science tourism, including geology, social and cultural, agricultural, ecological, industrial, as well as college and university-based popular science tourism. The popular science tourism industry in China has achieved a significant scale today.

2. Review

2.1. Popular science tourism

Reviewing the research process of popular science tourism throughout the years will play a crucial role in subsequent studies on this subject matter. The year 2000 marks a significant milestone in the development of popular science tourism in China, as prior to that time, research on this topic was still at its nascent stage. Popular science tourism has emerged in various forms across China, and its academic significance is becoming increasingly recognized by scholars who acknowledge it as a "new business model" for the industry. Since 2000, there has been a growing trend in research on popular science tourism, resulting in the development of an initial system for popular science tourism. This system is primarily based on geoparks as the main attraction for popular science tourism, supplemented by ecological and social-cultural elements to create a comprehensive experience. At this stage, significant progress has been made in popular science tourism in China, particularly with the establishment of popular science tourism resorts and the development of various reservations, like the feasibility study of Guangxi Huaping Natural Reservation Area [3], some forest parks, like the experience design of Junwu Forest Park in Suburb of Liuzhou [4], some geoparks, like the construction of evaluation system based on Henan Yuntaishan World Geopark [5]. Benefiting from diverse geographical landscapes, the exploration of natural elements has become a prominent feature in the development of popular science tourism in China. Since 2019, China's tourism market has been somewhat impacted, leading to a significant decline in research on popular science tourism. Nevertheless, it is undeniable that popular science tourism has garnered increasing attention in recent years. The research focus is still on geopark, such as Koktokay World Geopark [6] and Xiangxi UNESCO Global Geopark [7], and the study of tourist experience in Cuihua Mountain Landslide National Geopark [8]. The government emphasized in a 2022 document that all types of educational institutions and research centers should enhance their commitment to the dissemination of scientific knowledge, thereby highlighting the significance of university towns as popular science tourist destinations. Currently, China has established a relatively comprehensive system for popular science tourism, with geoparks and other geosciences as the main features [5–12] and other natural sciences serving as supplementary content [3,4,13–16].

In developed countries, where science tourism has matured earlier, it is not considered a distinct research topic. However, there are several relevant areas of interest such as industrial tourism, scientific tourism, venue tourism, university tourism and educational tourism. Since the 1980s, many European and American countries have recognized industrial tourism as an important part of the overall tourist market [17]. The study of industrial tourism primarily focuses on the concept of industrial tourism, the assessment of development potential for industrial heritage tourism resources, and the development and management strategies for industrial tourism. Among these areas, industrial heritage tourism is a particularly prominent topic in research on industrial tourism. In the 1990s, scholars began discussing the significance of mining areas and quarries as focal points for industrial heritage tourism. They conducted an in-depth study of Wales and Spain as case studies to evaluate the advantages and disadvantages of developing such sites [18]. Recently, there has been a growing body of research focusing on the sustainable development patterns of industrial tourist attractions. AR Szromek et al. conducted a study on the transformation of business patterns in industrial heritage tourism along the historic sites in Poland, providing detailed insights into various types of business models and their implementation [19]. The tourism behavior in venue tourism takes place in tourist destinations such as science and technology observation sites, science and technology exhibitions, and science and technology theme parks [20] and museums. Venue tourism research is approached from various perspectives, including examining the experiences of both tourists and destinations. Diamond conducted a study analyzing family interactions during museum visits across multiple families to compare parental and child behaviors in different households and

explore their mutual influence [21]. Boisvert attempted to conduct research by analyzing tourists' behaviors, collecting data on the duration of their stay at relevant tourism projects, and recording indicators reflecting their level of engagement. Based on his analysis, he obtained valuable findings that can contribute to enhancing the design of projects or exhibits [22]. Theologi-Goutti examined the process of establishing a science and technology museum at the University of Patras, analyzing the project design and emphasizing the significance of its establishment [23]. Starting from the perspective of venue tourism, Pedretti explored the potential for "upgrading" and future development directions of the Science Museum as one of the destination spots for venue tourism [24]. According to Connell's report on campus tourism, British universities have been utilizing their campus resources, such as dormitories, in order to generate additional income and alleviate the financial pressures caused by cuts in school funding. These universities have adopted two distinct business models for leveraging these resources: traditional and relatively new approaches. In the traditional utilization mode, the unused dormitory resources on campus of the university primarily serve educational holidays or study tours, providing tourists with opportunities to acquire knowledge and enhance their skills through services offered by the university. Conversely, in another utilization mode, only catering and accommodation services are utilized without other content [25]. Educational tourism can be traced back to the 17th and 18th centuries when aristocrats embarked on a popular travel trend known as the "Grand Tour". To date, numerous research findings have been published regarding the definition of educational tourism. Ritchie, B.W. posited that tourist activities can be categorized into two segments: the education-first segment for those who prioritize learning and knowledge acquisition during their overnight vacation or excursion, and the tourism-first segment for those whose primary focus is leisure and recreation [26]. Pit-man, T., Broomhall, S., and Majocha, E. contend that a type of tourism experience explicitly focused on providing structured learning in situ through active and engaged intellectual praxis is essential. Learning is integral and fundamental to the delivery of the product [27]. When considering the concept of educational tourism, one may initially associate it with "schools," "classrooms," "students," and "youth". However, the scope of educational tourism extends far beyond these traditional settings. Educational services can be provided in non-school environments such as dairy farms or through agricultural educational tourism [28]; Educational tourism is not limited to young people, as it can also cater to the elderly. Sie, L., Patterson, I., and Pegg, S. have developed a comprehensive framework that covers the three stages of educational tourism for seniors - pre-trip, during the trip, and post-trip - in order to provide a holistic review of their educational tourism experience [29]. Actually, in the western context, the meaning of science tourism is similar to that of popular science tourism. Or in other words, popular science tourism is a word that is closer to Chinese society. The difference is that science tourism emphasizes scientific knowledge, while popular science tourism pays attention to science, nature and culture. Meanwhile, popular science tourism places more emphasis on being accessible and easily understood with the purpose of enhancing people's scientific and cultural literacy. Morse believes that science tourism can be traced back to the 19th century, with the rise travel exploration for scientific research [30]. This kind of travel is more like a scientific expedition rather than science tourism. Nevertheless, many scholars still concur that scientific expeditions are an integral part of science tourism [31] and posit that this form of tourism can significantly contribute to sustainable development. For instance, Buzinde et al. advocate for the potential of researchers' science tourism in promoting sustainable development within indigenous communities [32], while Izurieta et al. have demonstrated how scholars' engagement in science tourism has facilitated the achievement of Sustainable Development Goals, fostered community cohesion, and preserved cultural and ancestral values [33]. However, there are diverse opinions suggesting that science tourism can be categorized into visiting, listening to explanations, and hands-on participation ([34] cited from Ereshko F. I., 2006). For instance, Räikkönen et al. conducted a study on the motivations of tourists for natural science tourism in Seili Island, Finland revealed that the primary motivation behind science tourism is learning purposes [35].

2.2. Tourism and universities

Universities were traditionally viewed as institutions for teaching and scientific research, with little association to tourism. However, in the context of the knowledge economy, universities have gradually taken on additional roles such as contributing to a city's sustainable development, serving as cultural icons and symbols, and driving urban innovation [36]. Therefore, the interconnectivity between the campus and the city has become increasingly crucial in shaping a socio-economic environment of innovation through talent attraction and retention, as well as knowledge creation and application for enhancing the region's economic development [37]. For instance, the University of Chicago is widely recognized as a hub for leisure activities among its residents, a center for fostering scientific and technological advancements, a significant cultural institution and tourist destination within the city, all while generating numerous employment opportunities and driving economic growth in Chicago [38], and the University of Cambridge, as an exemplar of urban-university integration, transcended the conventional demarcation between campus and city during its construction. The city provides a conducive milieu for the university's growth, while the university furnishes the city with a humanistic bedrock and augments its developmental potential. As an integral part of the city center, the University of Cambridge offers a range of services and leisure activities to the surrounding community, thereby increasing its appeal as both a tourist destination and a place to live [39]. The concept of tourism in colleges and universities is currently at the forefront of destination marketing, particularly in China where it has been recognized as a phenomenon worthy of investigation [40]. In China, the development of higher education and the expansion of school sizes have led to the emergence of university towns as a new model for urban and regional growth. The construction of these towns began taking shape in 2006. The favorable environmental conditions in many university towns have drawn the attention of scholars, who propose further optimization of these areas to enhance their ecological and educational value [41]. Taking Nanjing Xianlin University Town as a case study, Yin and Huang examine the principles and strategies of tourism development in Xianlin University Town, while also conducting a preliminary exploration into the tourism potential of Chinese university towns [42]. Resource sharing is recognized as a crucial concept in the development of university towns in China [43], serving

as a key driver for facilitating information and resource exchange between university towns and cities. The majority of scholars contend that promoting such exchanges can foster the healthy and orderly growth of university towns, facilitate coordination and integration with surrounding cities, and promote mutual development [44]. Therefore, the increasingly close relationship between university towns and cities is an inevitable trend in the development of university towns, representing efficient resource utilization. Scholars have identified Guangzhou HEMC as a destination for popular science tourism through spatial analysis, and the value of it as a popular science tourism destination was further explored [45]. University town tourism serves as an effective means of transmitting scientific knowledge and sharing development information between urban areas and university towns, thereby strengthening their connection. The immense value of university towns as popular science tourism destinations cannot be overlooked.

2.3. Evaluation of popular science tourism

The assessment of science tourism involves evaluating and analyzing the resources, development status, potential for growth, and impact factors of science tourism in tourist destinations. This enables the identification of modifying measures to address future challenges. Chinese scholars have few studies on the evaluation of popular science tourism, mainly about the evaluation and analysis of natural resources such as geoparks and natural parks, but little attention has been paid to the satisfaction of tourists.

The assessment of geoparks and natural parks development is a crucial aspect in the research of popular science tourism, given China's abundant resources in these fields. Generally speaking, the analytic hierarchy process (AHP) [6,11,15] and SWOT analysis [6,7,9,11] are the most commonly utilized method. The evaluation system of forest park science popularization resources was constructed by Wang et al. using AHP, which holds significant guidance for the development of forest science popularization tourism products [15]. The sustainable popular science tourism of Xiangxi UNESCO Global Geopark was investigated by Wang et al. using the SWOT method, and its participation mode was explored to a certain extent [7]. In fact, to address the limitations of these two methods, more studies have integrated them in order to achieve a comprehensive evaluation. Long et al. evaluated Koktokay World Geopark through the method of SWOT-AHP [6]. However, the majority of previous studies have focused on the original development of popular science tourism, neglecting the subsequent tracking and advancement of popular science tourism destinations. Moreover, tourists constitute the primary stakeholder group in tourism, making it challenging to implement changes that meet their expectations without taking into account their opinions and sentiments. Furthermore, popular science tourism must cater to the general public. Fieldwork, as the primary method for conducting on-site visitor surveys, possesses greater explanatory power in this instance. Nevertheless, there exist a limited number of studies that examine tourists' experiences in popular science tourism [10,46], they have yet to become the primary focus of research in this field.

Our team has conducted a preliminary assessment of the potential value of popular science tourism in Guangzhou Higher Education Mega Center using AHP and GIS methodologies, and we have determined that it possesses significant potential as a destination for such tourism [45]. In order to further explore the value of popular science tourism in Guangzhou Higher Education Mega Center, we build upon previous research by adopting a more micro and people-oriented perspective. Our study seeks to address the following inquiry: What is the overall satisfaction level of tourists regarding popular science tourism in Guangzhou Higher Education Mega Center? By addressing this query, we will also explore additional questions such as: Which aspects of Guangzhou Higher Education Mega Center contribute significantly to visitor satisfaction? What areas require improvement for future development? What do these findings suggest for the development of other science tourism places? Through these efforts, we hope to provide valuable insights and ideas for popular science tourism destinations while also exploring the potential of university towns as popular science tourism hotspots.

3. Materials and methods

3.1. Study area

The Guangzhou Higher Education Mega Center (hereinafter referred to as "Guangzhou HEMC") is situated on Xiaoguwei Island, a vital node of the Pearl River space belt. It comprises 12 universities and colleges, including Sun Yat-sen University, South China Normal University, and South China University of Technology. Additionally, it houses the Guangdong Science Center, Lingnan Impression, Guangzhou National Archives, and other tourist attractions. Guangzhou HEMC boasts a plethora of universities, picturesque surroundings, convenient transportation, comprehensive infrastructure, abundant scientific resources and a thriving research culture. As such, it has gradually emerged as a popular destination for science tourism. However, there is still untapped potential in Guangzhou HEMC's capacity to attract visitors interested in science popularization.

3.2. Ethical approval

This study was approved by the Ethics Committee of School of Geography and Remote Sensing, Guangzhou University. Written informed consent was obtained from all the participants. The questionnaires were anonymized, and patients were free to opt out of participation in the study whenever they were uncomfortable.

3.3. American customer satisfaction index

Among the large number of currently available approaches for studying customer satisfaction, there is the Swedish barometer (SCSB) [47], the American customer satisfaction index (ACSI) [48], the European customer satisfaction index (ECSI) [49], the

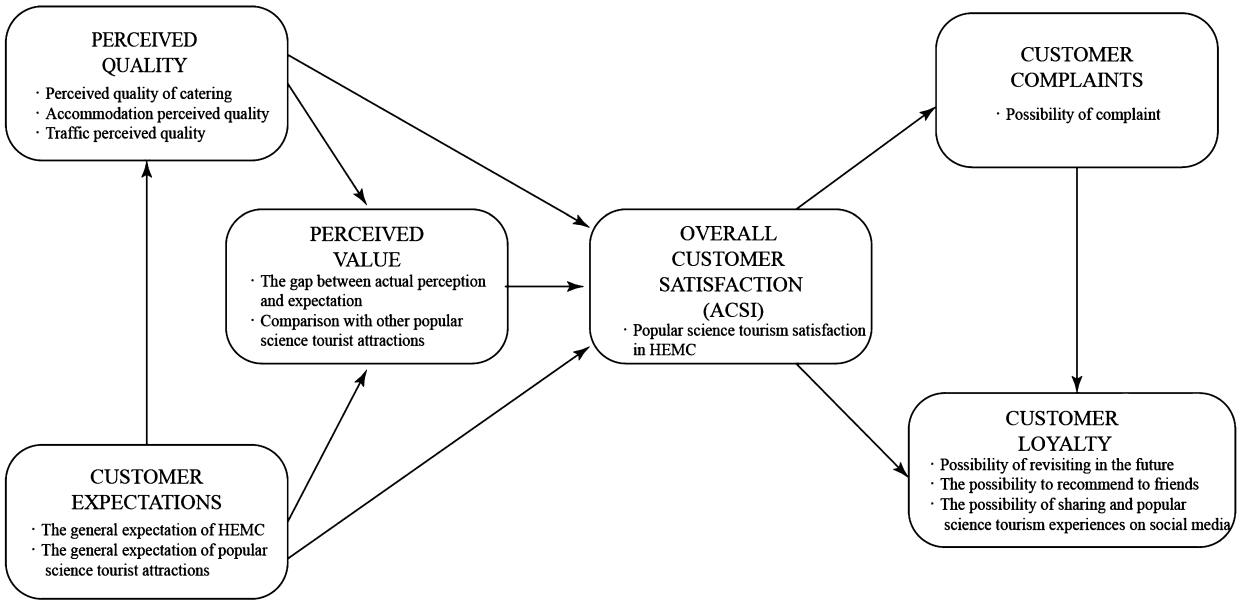

Fig. 1. American customer satisfaction index model [48] in this case.

Norwegian customer satisfaction barometer (NCSB) [50] and so on. ACSI is a widely adopted evaluation model in current use. As a comprehensive method for assessing customer satisfaction, ACSI not only takes into account actual consumption experiences but also places greater emphasis on predicting future prospects [51]. The American Customer Satisfaction Index (ACSI) model is developed based on the SCSB model, which assesses consumers' perceptions of goods and services quality. This model comprises macro and micro models, with the former illustrated in Fig. 1. This model elucidates the interplay among six potential variables, namely perceived quality, perceived value, customer expectations, customer satisfaction, customer complaints and customer loyalty in the entire process of achieving optimal levels of customer satisfaction. Perceived quality, perceived value and customer expectation are identified as antecedents while perceived quality is found to be a decisive factor with both customer complaints and loyalty being outcomes [48]. The ACSI model was initially developed for product market evaluation and subsequently applied to tourism research. Its application in the study of tourism satisfaction by numerous scholars attests to its explanatory power within this field, and it has been used in China's tourism studies [52,53]. In the model, there is a positive correlation between customer expectations and perceived value, perceived quality, and customer satisfaction. Additionally, perceived quality and perceived value are positively associated with customer satisfaction. Perceived value also has a positive relationship with customer satisfaction. Finally, there is a negative correlation between customer complaints and customer satisfaction, while there is a positive correlation between customer loyalty and customer satisfaction [48]. In general, there are numerous approaches to solving the macro model, with structural equation modeling (SEM) being the most widely used. SEM is a multivariate statistical analysis technique employed to examine the relationship between latent variables (i.e., structural variables) and manifest variables (i.e., observed variables), as well as the relationship between latent variables themselves [54]. The Partial Least Squares (PLS) method was employed for SEM [55–57], and there exist sophisticated tools such as SmartPLS [58] for its computation. These softwares possess robust functionalities, enabling the completion of a series of structural equation model modeling and calculations, as well as automatic computation of goodness-of-fit and other related data processing, which are potent tools for analyzing questionnaires. In social science research, data may not conform to a normal distribution. PLS-SEM is more suitable than CB-SEM at this time [59]. In cases where there is a need to validate and confirm existing theories, CB-SEM is the first choice. But in terms of theoretical development and prediction, PLS-SEM is superior [60] because PLS-SEM allows model estimation by combining interpretation and prediction perspectives, and its joint consideration is the main concern of most social science researches [59].

The micro model is a formula utilized to normalize all satisfaction scores and measure the satisfaction index accurately. The formula is as shown in (1) [47]

$$CSI = \frac{E[CS] - min[CS]}{max[CS] - min[CS]} \times 100 \tag{1}$$

Where, CSI represents the customer satisfaction index, E[CS], max[CS], and min[CS] respectively denote the mean, maximum, and minimum values of customers' satisfaction scores.

Research on customer satisfaction has a rich history, with satisfaction becoming a formal research field in marketing since Cardozo's introduction of the concept [61]. The study of tourist destination satisfaction has its roots in the research on product and service quality within the manufacturing industry. In the 1970s, Pizam and other American scholars conducted studies on tourist satisfaction in destinations, laying a foundation for the development of theories related to this topic [62]. In the American Customer Satisfaction Index, customer satisfaction is determined by factors such as customer expectations, perceived quality, and perceived

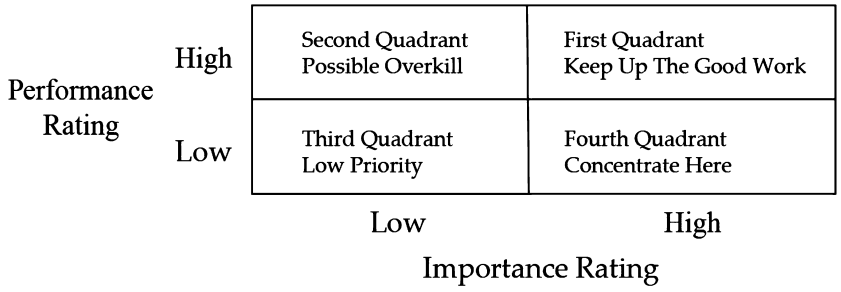

Fig. 2. Location analysis diagram of IPA (Adapted from figure by Song et al. [69]).

value. Customer expectations are based on past empirical or non-empirical information that customers use to judge and predict the quality of products or services [63]. As for the perception of quality, Zeithaml posits that it is a higher-level abstract perception encompassing all product attributes and an overall judgment [64], and Parasuraman et al., on the other hand, define it as customers' evaluations of a product's overall excellence [65]. The perceived value refers to the balance of benefits between the acquired and paid components for customers. The acquired component pertains to quality and utility benefits obtained from purchased products, while the paid component includes monetary costs as well as non-monetary expenses such as time and energy [66]. Besides, customer complaints are an expression of dissatisfaction with the enterprise, indicating a desire for operational changes and improvements in product or service quality. Seeking compensation is essentially a means to achieve this end [63]. In contrast, customer loyalty refers to the intentional and repeated purchase behavior of a certain brand's products over the long term [67]. In tourism research, customer complaints can be interpreted as an indication of tourists' willingness to enhance the quality of a scenic spot, according to Fornell and Liu [63]. Meanwhile, customer loyalty can be defined as a long-term and intentionally biased repeated behavior towards a specific scenic spot by tourists, as suggested by Jacoby and Chestnut [67]. In this paper, ACSI model will be used to conduct multivariate analysis on the perceived quality and perceived value of the collected tourist questionnaires, so as to obtain the overall customer satisfaction of Guangzhou HEMC science popularization tourism, and analyze the customer complaints and customer loyalty.

3.4. Importance-performance analysis

The importance-performance analysis (IPA), was initially proposed by Martilla and James in 1977, which compares the importance of customer expectations or requirements with their actual perceptions of satisfaction towards a project [68]. In the course of continuous development, IPA analysis has been widely applied across various fields to consistently enhance service quality. Particularly in the tourism industry, IPA has reached a level of maturity in its application [69–72]. The strengths of IPA analysis lie in its intuitive imagery, clear model, and reader-friendly nature. However, the weakness lies in the assumption that variables within the two dimensions of importance and satisfaction are independent and linearly correlated with respondents' overall perception. However, in actual surveys, respondents' evaluations are typically based on subjective perceptions and their assessments of importance and satisfaction are often interdependent. The assumptions required by traditional IPA analysis methods can be challenging to meet, and the resulting element quadrant distributions may not always have a reasonable explanation. Secondly, conducting an IPA analysis necessitates respondents to provide dual evaluations for the same question. As the number of questionnaire items increases, survey duration may extend while survey quality could potentially deteriorate [73].

SmartPLS has developed an IPA analysis mode that utilizes path coefficients as indicators of importance and normalized values as performance, which enables the IPA analysis to be performed on questionnaires with one dimensional variables, thereby introducing a novel expression format for the previously singular structural equation model analysis questionnaire [74,75].

Initially, the significance (I) and corresponding performance (P) score of each observed variable were determined to create a graph frame depicting the IP scale. Next, the average values of importance and performance scores were calculated, represented by a dotted line intersecting in the IP diagram. Subsequently, observed variables were allocated to four quadrants based on their respective importance and actual performance scores. Finally, in accordance with Baloglu and Love's research [76], the four quadrants were interpreted as follows: Quadrant I (high/high) represents a prominent emphasis and remarkable results, with the recommendation to maintain efforts (Keep Up The Good Work). Quadrant II (low/high) represents low significance but significant results, with the suggestion to avoid deliberate pursuit (Possible Overkill). Quadrant III (low/low) represents poor performance and low significance, requiring gradual development (Low Priority). Quadrant IV (high/low) indicates high significance but poor performance, suggesting a need for improvement in this area (Focus Here) (as shown in Fig. 2).

3.5. Design of questionnaire and variables

This study utilized a questionnaire survey to collect data, which was divided into three parts. The first part included basic information about the questionnaire, such as personal information confidentiality and the purpose of the survey. The second part measured the latent variable of tourism satisfaction evaluation using questions based on the American Customer Satisfaction Index model [48], combined with the evaluation index of popular science tourism constructed by Shen and Zhao [46] and perceived quality items by He [77]. The questionnaire items we refer to have been validated in their studies. The dimensions related to

Table 1
Design of variables.

Construct	Item	Explanation
Customer expectations	EX1	General expectation of popular science tourist attractions
	EX2	The general expectation of Guangzhou HEMC
	EX3	Expectations of features/cultural and creative products
Perceived catering quality	CA1	Food and beverage safety and hygiene
	CA2	Reasonable food and beverage prices
	CA3	Convenience of food and beverage distribution
Perceived accommodation quality	AC1	Comfort of accommodation environment
	AC2	Accommodation price rationality
	AC3	Accommodation distribution convenience
Perceived transportation quality	TR1	Accessibility of transportation to Guangzhou HEMC
	TR2	The convenience of internal transportation conditions
	TR3	Traffic comfort or parking convenience
Perceived environment quality	EN1	Satisfaction with human and natural landscape
	EN2	Satisfaction with popular science tourism resources
	EN3	Satisfaction with environmental health status
	EN4	Satisfaction with safety facilities
	EN5	Satisfaction with congestion in scenic spots
Perceived service quality	SE1	Satisfaction with science knowledge explanation of staff
	SE2	Satisfaction with service attitude of staff
	SE3	Satisfaction with infrastructure set reasonable
Perceived value	PV1	Satisfaction with pricing of scenic products and services
	PV2	Satisfaction with the quality of popular science tourism products and services
	PV3	Expanded knowledge, understood science popularization more profoundly
Customer satisfaction	SA1	The overall satisfaction with popular science tourism in Guangzhou HEMC
	SA2	Satisfaction comaired with the expected gap
	SA3	Satisfaction compared with other popular science tourism attractions
Customer complaints	CO1	The possibility of complaining to the scenic area
	CO2	The possibility of filing a complaint with local authorities
	CO3	The possibility of expressing dissatisfaction with popular science products
Customer loyalty	LO1	The possibility of future revisits
	LO2	The likelihood of referral to relatives and friends
	LO3	The likelihood of publishing to the Internet to promote popular science tourism

The table explains what each item of each variable represents. The first-order variables, including perceived catering quality, perceived accommodation quality, perceived transportation quality, perceived environment quality and perceived service quality are subsumed under the second-order variable of "perceived quality".

popular science were adjusted in accordance with the research content. For instance, customer expectations encompass tourists' anticipation of popular science tourism at HEMC; perceived quality encompasses tourists' assessment of popular science services and facilities; customer satisfaction includes tourists' contentment with popular science content; perceived value comprises tourists' evaluation of the quality of popular science, among others. The third component pertains to the collection of demographic variables, encompassing gender, age, education level, income and other relevant factors. All observed indicators were assessed utilizing a 5-point Likert scale [78]. The designed questionnaire will undergo a professional review and be modified accordingly to form a formal version, with the variables outlined in Table 1.

3.6. Tourist satisfaction index

To more accurately reflect the level of tourist satisfaction, we utilized the TSI index, derived from Fornell's customer satisfaction index, to calculate their specific degree of satisfaction [47]. The formula is as shown in (2):

$$TSI = \frac{E[TS] - min[TS]}{max[TS] - min[TS]} \times 100 \tag{2}$$

TSI represents the overall satisfaction of tourists, while E[TS], max[TS], and min[TS] respectively denote the mean, maximum, and minimum values of perception variables corresponding to tourists.

3.7. Data collection and descriptive statistical analysis of samples

Through the method of field survey, paper questionnaires were distributed in various crowded areas within Guangzhou HEMC during October to November 2023. To ensure data reliability, only tourists to Guangzhou HEMC were surveyed. With the exception

Table 2
Sample descriptive statistics.

Demographic variables	Item	Sample size	Percentage
Gender	Male	123	43.93%
	Female	149	53.21%
Age	6 or below	2	0.71%
	7-16	27	9.64%
	17-28	139	49.64%
	29-50	100	35.71%
	50 or above	5	1.79%
Education background	Junior high school or below	33	11.79%
	Senior high school (or technical secondary school)	4	1.43%
	Junior college	29	10.36%
	Undergraduate	154	55.00%
	Postgraduate or above	53	18.93%
District	In Guangzhou city	188	67.14%
	Out of Guangzhou city, in Guangdong province	52	18.57%
	Out of Guangdong province	33	11.79%
Job	Civil servant	6	2.14%
	Institution staff	29	10.36%
	Student	137	48.93%
	Soldier	1	0.36%
	Enterprise staff	62	22.14%
	The emeritus and retired	4	1.43%
	Freelancer	24	8.57%
	Others	8	2.86%
Income	No income	138	49.29%
	2300CNY or less	10	3.57%
	2301-5000CNY	6	2.14%
	5001-8000CNY	26	9.29%
	8001-12000CNY	41	14.64%
	12001-20000CNY	23	8.21%
	More than 20000CNY	27	9.64%

The table visually shows the gender, age and other relevant information of the respondents and their percentage.

of demographic information, all important observations were not missing. A total of 345 questionnaires were collected, with 280 valid questionnaires retained after removing samples with an overlap degree exceeding 70%, resulting in an effective rate of 81.16%.

4. Results

4.1. Demographic features of respondents

The statistical results unveil the demographic characteristics of tourists at Guangzhou HEMC. The total count for each demographic variable does not add up to 280 due to some respondents opting out of providing their information. As is shown in Table 2, the proportion of men and women who filled out the questionnaire was roughly equal, and the main characteristics of the groups who filled out the questionnaire were: those aged between 17 and 28 (49.64%), those who were undergraduates or had bachelor's degree (55%), those who were local to Guangzhou city (67.14%), those whose job was student (48.93%), and those who had no income (49.29%).

4.2. Reliability and validity testing

KMO, Cronbach's α, average values and standard deviation were analyzed using SPSS28 [79], while factor loadings, structure validity and collinearity were analyzed using SmartPLS4 [58]. The PLS-SEM algorithm of SmartPLS4 was used in this part. As presented in Table 3, all factor loads except EN5 and LO3 exceeded 0.7; the factor loads of EN5 and LO3 surpassed 0.6 but remained within an acceptable range. This indicates that the observed variables effectively explicate latent variables [80]. The reliability test was conducted using SPSS, and the **Cronbach's α coefficient of the questionnaire as a whole was 0.903**, indicating that the questionnaire exhibited good internal consistency and stability. Additionally, both KMO and Bartlett tests were performed with **KMO = 0.906**, demonstrating strong correlations between variables suitable for factor analysis. According to Nunnally and Bernstein [81], composite reliability values ranging from 0.60 to 0.70 are deemed acceptable in exploratory research, while values between 0.70 and 0.90 are considered satisfactory in more advanced stages of research. As shown in Table 3, the composite reliability and Cronbach's α of all latent variables, except for customer expectation, exceed 0.7. However, the Cronbach's α of customer expectation is above 0.6, which falls within an acceptable range indicating good internal consistency and reliability.

Table 3
Reliability and validity testing.

Construct	Item	Average values	Standard diviation	Loadings	Cronbach's α	CR	AVE
Customer expectations	EX1	3.56	0.95	0.805	0.648	0.81	0.588
	EX2	3.69	0.87	0.783			
	EX3	3.34	0.86	0.709			
Perceived catering quality	CA1	3.21	0.83	0.8	0.721	0.842	0.64
	CA2	3.31	0.75	0.774			
	CA3	3.14	0.91	0.825			
Perceived accommodation quality	AC1	3.24	0.89	0.826	0.798	0.881	0.713
	AC2	3.2	0.67	0.836			
	AC3	3.19	0.82	0.869			
Perceived transportation quality	TR1	3.43	0.96	0.877	0.804	0.884	0.719
	TR2	3.49	0.91	0.891			
	TR3	3.37	0.96	0.771			
Perceived environment quality	EN1	3.66	0.85	0.735	0.8	0.862	0.557
	EN2	3.46	0.92	0.8			
	EN3	3.49	0.84	0.752			
	EN4	3.42	0.84	0.795			
	EN5	3.35	0.91	0.64			
Perceived service quality	SE1	3.38	0.88	0.881	0.72	0.845	0.649
	SE2	3.53	0.8	0.877			
	SE3	3.01	0.87	0.634			
Perceived value	PV1	3.31	0.8	0.823	0.702	0.834	0.627
	PV2	3.26	0.75	0.832			
	PV3	3.59	0.88	0.714			
Customer satisfaction	SA1	3.36	0.78	0.832	0.783	0.874	0.698
	SA2	3.49	0.72	0.799			
	SA3	3.63	0.86	0.873			
Customer complaints	CO1	1.7	0.86	0.91	0.779	0.872	0.695
	CO2	1.9	1.05	0.809			
	CO3	1.81	0.98	0.776			
Customer loyalty	LO1	3.62	1.06	0.905	0.76	0.862	0.68
	LO2	3.57	1.01	0.896			
	LO3	2.89	1.12	0.645			

The first-order variables, including perceived catering quality, perceived accommodation quality, perceived transportation quality, perceived environment quality and perceived service quality are subsumed under the second-order variable of "perceived quality". Only the parameters of the first-order variables are reported in the table.

The validity testing was conducted based on the calculated results of SmartPLS4. The questionnaire's validity can be assessed in terms of convergent and discriminant validity, with AVE representing the average variance extracted value. According to Fornell and Larcker, a scale is considered to have good convergent validity when its AVE value exceeds 0.5 [82]. The average value of all latent variables exceeds 0.5, indicating the questionnaire's strong convergent validity.

The Fornell-Larcker criterion is utilized to assess discriminant validity, which involves comparing the square root of the average variance extracted (AVE) for each latent variable with the correlation coefficients between variables [82]. As shown in Table 4, the diagonal line represents the square root of AVE for the latent variable, while the remaining cells indicate the correlation coefficients between each pair of latent variables. The fact that all square roots of AVE are greater than their respective correlation coefficients suggests good discriminant validity in our sample.

The HTMT is a criterion to assess discriminant validity more rigorous [83]. In general, the HTMT value should not exceed 0.9, and ideally be below 0.85. As indicated in Table 5, two items failed to meet this criterion; therefore, we eliminated one of them to reduce the HTMT value and comply with the requirement. The revised indicators are shown in Table, all of which have reached a good standard.

The modified results are shown in the Table 6, 7 and 8, and it can be found that the indicators meet the requirements better.

4.3. Model fitting

The model was calculated by partial least square method, and SmartPLS4 [58] was use as computing tool.

R^2 represents the standard of predictive power in the sample and reflects the degree of variation in interpretation among each endogenous variable [84]. A higher value indicates greater accuracy in prediction. Normally, the R^2 is required to be between 0 and

Table 4
Discriminant validity (Fornell-Larcker criterion).

	TR	AC	PV	SE	EN	LO	CO	EX	SA	CA
TR	0.848									
AC	0.479	0.844								
PV	0.409	0.500	0.792							
SE	0.471	0.539	0.653	0.806						
EN	0.527	0.561	0.631	0.649	0.747					
LO	0.237	0.221	0.262	0.221	0.361	0.824				
CO	-0.205	-0.090	-0.304	-0.252	-0.292	-0.029	0.833			
EX	0.361	0.433	0.462	0.399	0.514	0.319	-0.089	0.767		
SA	0.422	0.468	0.702	0.651	0.661	0.310	-0.314	0.444	0.835	
CA	0.528	0.596	0.523	0.502	0.557	0.259	-0.202	0.480	0.496	0.800

The value below each column needs to be smaller than the first.

Table 5
Discriminant validity (HTMT).

	TR	AC	PV	SE	EN	LO	CO	EX	SA	CA
AC										
CA	0.773									
CO	0.125	0.258								
EN	0.695	0.719	0.374							
EX	0.604	0.693	0.14	0.703						
LO	0.284	0.342	0.142	0.446	0.446					
PV	0.656	0.726	0.412	0.84	0.69	0.342				
SA	0.591	0.65	0.4	0.828	0.617	0.385	**0.96**			
SE	0.706	0.679	0.336	0.842	0.561	0.274	**0.907**	0.855		
TR	0.589	0.677	0.253	0.647	0.488	0.307	0.523	0.523	0.62	

<0.85: fine; 0.85-0.9: acceptable; >0.9: poor.

Table 6
Revised data.

Construct	Item	Average values	Standard diviation	Loadings	Cronbach's α	CR	AVE
Perceived value	PV1	3.31	0.8	0.867	0.686	0.864	0.761
	PV2	3.26	0.75	0.878			

Table 7
Revised discriminant validity (Fornell-Larcker criterion).

	AC	CA	CO	EN	EX	LO	PV	SA	SE	TR
AC	0.844									
CA	0.596	0.8								
CO	-0.09	-0.202	0.833							
EN	0.561	0.557	-0.292	0.747						
EX	0.433	0.48	-0.089	0.514	0.767					
LO	0.221	0.259	-0.029	0.361	0.319	0.824				
PV	0.512	0.508	-0.278	0.593	0.415	0.255	0.872			
SA	0.468	0.496	-0.314	0.66	0.443	0.31	0.618	0.836		
SE	0.539	0.502	-0.252	0.649	0.399	0.221	0.63	0.65	0.806	
TR	0.479	0.528	-0.205	0.527	0.361	0.237	0.428	0.421	0.471	0.848

The value below each column needs to be smaller than the first.

1, and the closer to 1, the better the model fit. As is shown in Table 9, the R^2 is all greater than 0, indicating that the model fitting degree is fine.

Q^2 was originally calculated using blindfolding, but smartPLS4 has removed this feature and the out of sample forecast is now using PLSpredict. Q^2 predict, root mean square error (RMSE) and mean absolute error (MAE) were calculated by PLSpredict [85], which represent the predictive power out of sample and the accuracy of variables. The prevailing belief is that when q reaches a level of 0.02, it exhibits weak out-of-sample predictive capability; at a level of 0.15, it demonstrates moderate prediction ability; and at a level of 0.35, it showcases strong prediction capacity [86]. As is shown in Table 10, the effect size (f^2) represents the magnitude of each independent variable's impact on the dependent variable. By measuring the variance in square correlation values, it can determine whether predictor variables have a significant influence on the value of the dependent variable [87].

Variance inflation factor (VIF) stands for multicollinearity, usually less than 5 and ideally less than 3 [87]. As shown in Table 11, all VIFs are in good range.

Table 8
Revised discriminant validity (HTMT).

	AC	CA	CO	EN	EX	LO	PV	SA	SE	TR
AC										
CA	0.773									
CO	0.125	0.258								
EN	0.695	0.719	0.374							
EX	0.604	0.693	0.14	0.703						
LO	0.284	0.342	0.142	0.446	0.446					
PV	0.69	0.722	0.379	0.802	0.623	0.34				
SA	0.591	0.65	0.4	0.828	0.617	0.385	0.844			
SE	0.706	0.679	0.336	0.842	0.561	0.274	0.895	0.855		
TR	0.589	0.677	0.253	0.647	0.488	0.307	0.572	0.523	0.62	

<0.85: fine; 0.85 0.9: acceptable; >0.9: poor.

Table 9
Fitting indexes and prediction indexes.

	AC	CA	CO	EN	LO	PQ	PV	SA	SE	TR
R^2	0.625	0.611	0.098	0.746	0.101	0.309	0.459	0.521	0.631	0.544
R^2 adjusted	0.623	0.61	0.095	0.745	0.095	0.307	0.455	0.516	0.63	0.542
Q^2 predict	0.18	0.222	−0.001	0.254	0.066	0.298	0.161	0.185	0.149	0.121
RMSE	0.914	0.89	1.015	0.87	0.973	0.843	0.924	0.911	0.93	0.944
MAE	0.72	0.704	0.814	0.662	0.777	0.638	0.729	0.706	0.738	0.756

R^2 and R^2 adjusted: between 0 and 1, the higher the better; Q^2 predict: 0.02: weak predictive, 0.15: medium predictive, 0.35: strong predictive; MAE better be less than RMSE.

Table 10
f^2 (second-order variable eliminated).

	AC	CA	CO	EN	EX	LO	PV	SA	SE	TR
CO					**0.006**					
EX						0.448	**0.004**	**0.007**		
PQ	1.665	1.571		2.937			0.53	0.202	1.711	1.193
PV								0.086		
SA			0.109		0.112					

>0.1: fine; <0.1: poor.

Table 11
VIF (second-order variable eliminated).

	CO	LO	PV	SA
CO		1.109		
EX			1.448	1.454
PV				1.848
SA	1	1.109		

<3: fine.

4.4. Macro model analysis results

As is shown in Table 12, there are three unsupported paths: the path from customer complaint to customer loyalty, the path from customer expectation to perceived value, and the path from customer expectation to customer satisfaction, while the other paths are well supported. We speculate that this is caused by tourists' lack of knowledge of popular science tourism, or relevant resources in the Guangzhou HEMC. Among the three determinants correlating tourists' satisfaction with popular science tourism, perceived quality and perceived value have significant positive correlations, which indicates that high-quality, cost-effective and effective popular science tourism is very important for tourists' satisfaction. Meanwhile, compared with the path of perceived value to customer satisfaction, the path coefficient of perceived quality to customer satisfaction is higher, same conclusion as Anderson et al. [88], which shows that it is more important to improve the cost performance of science popularization resources, indicating the significance of quality strategy.

There was also a significant positive correlation among the determinants of satisfaction. This shows that the expectation of popular science tourism can change the perception of the quality of popular science tourism, and tourists improve their perception of the value of popular science tourism by perceiving the quality of popular science tourism, indicating that the importance of improving the publicity and the quality of popular science tourism in Guangzhou HEMC.

Table 12
Path analysis results.

Paths	Original sample	Sample mean	Standard deviation	Path coefficients	T statistics	P values	95%CI		Testing results
							LLCI	ULCI	
CO → LO	0.076	0.078	0.072	0.076	1.056	0.291	-0.063	0.222	nonsupport
EX → PQ	0.556	0.56	0.051	0.556	11.009	0	0.452	0.65	support
EX → PV	0.056	0.061	0.055	0.056	1.029	0.303	-0.043	0.172	nonsupport
EX → SA	0.071	0.071	0.055	0.071	1.301	0.193	-0.035	0.18	nonsupport
PQ → PV	0.644	0.642	0.05	0.644	13.001	0	0.536	0.731	support
PQ → SA	0.463	0.463	0.069	0.463	6.703	0	0.325	0.596	support
PV → SA	0.276	0.278	0.068	0.276	4.072	0	0.144	0.408	support
SA → CO	-0.314	-0.322	0.078	-0.314	4.009	0	-0.47	-0.166	support
SA → LO	0.334	0.339	0.062	0.334	5.352	0	0.213	0.455	support

CI = confidence interval, LLCI = lower limit confidence interval, ULCI = upper limit confidence interval.

Table 13
Tourists' satisfaction.

Satisfaction types (SA1-SA3)	TSI
Overall satisfaction with popular science tourism in Guangzhou HEMC	59.11
The gap with expectations	62.32
The gap with other popular science tourism destinations	65.71

TSI = tourists' satisfaction index.

Although perceived quality has a greater correlation on satisfaction, the factor of price cannot be disregarded. The significant correlation of expectation on perceived quality highlights the importance of early publicity. Therefore, publicity, quality and price are all crucial factors that must not be overlooked; however, priority should be given to publicity and quality.

There are three paths between the satisfaction of popular science tourism and the two exogenous variables. Popular science tourism satisfaction has a significant positive correlation to customer loyalty and a significant negative correlation to customer complaints. This is consistent with the hypothesis of previous studies.

4.5. The tourist satisfaction

The tourist satisfaction indexes calculated by formula are shown in Table 13. As is shown in Table 13, the overall satisfaction level of tourists falls short, failing to reach even 60. However, in comparison with the anticipated popular science tourism, the satisfaction level among tourists is slightly higher than the overall degree. This suggests that their initial expectations were already low and highlights a lack of understanding regarding popular science tourism. The root cause lies in the inadequate publicity of popular science tourism, resulting in tourists' lack of awareness and interest in this type of tourism. Nonetheless, compared to other popular science destinations, the university town remains competitive as tourist satisfaction has slightly increased. The root cause lies in the fact that although the popular science tourism industry is currently thriving, its level of development may still be insufficient. This indicates that one direction for future work is to develop more popular science resources and destinations for tourism, in order to meet the public and social demand for scientific knowledge.

4.6. Importance-performance of customer satisfaction

The importance-performance analysis is visualized as Fig. 3. As shown in the Fig. 3, SE1, SE2, EN2, EN4 and TR1 are located in the first quadrant and correspond to science knowledge explanation, service attitude, popular science tourism resources, safety facilities and accessibility of transportation to Guangzhou HEMC. These factors are crucial for maintaining high performance standards. This indicates that the scientific tourism content and services in the Guangzhou HEMC are of high quality, with good accessibility as well.

TR2, EN1, TR3 and EN5 are situated in the second quadrant, corresponding respectively to internal transportation convenience, human and natural landscapes, traffic comfort or parking convenience, and congestion in scenic spots. Although these factors perform well, they do not appear to be of significant importance and can therefore continue naturally as is. But during our research, we discovered that some tourists expressed concerns regarding potential traffic congestion and inadequate parking facilities for self-driving trips during holiday periods to and from the island.

CA2, AC1, CA3, SE3 and EN3 are situated in the third quadrant and correspond to catering service prices, comfort of accommodation environment, convenience of catering services distribution, infrastructure sets and environmental health status. These factors do not exhibit satisfactory performance but neither are they deemed important, hence they can be considered as "low priority". During our research, we discovered that the majority of tourists bring their own provisions, resulting in a relatively low demand for catering services. Additionally, due to the short duration of most tourist stays, there is not a significant need for lodging accommodations. However, some visitors have reported inadequate public restroom facilities and excessive litter on the grassy areas, indicating suboptimal environmental conditions and infrastructure conditions.

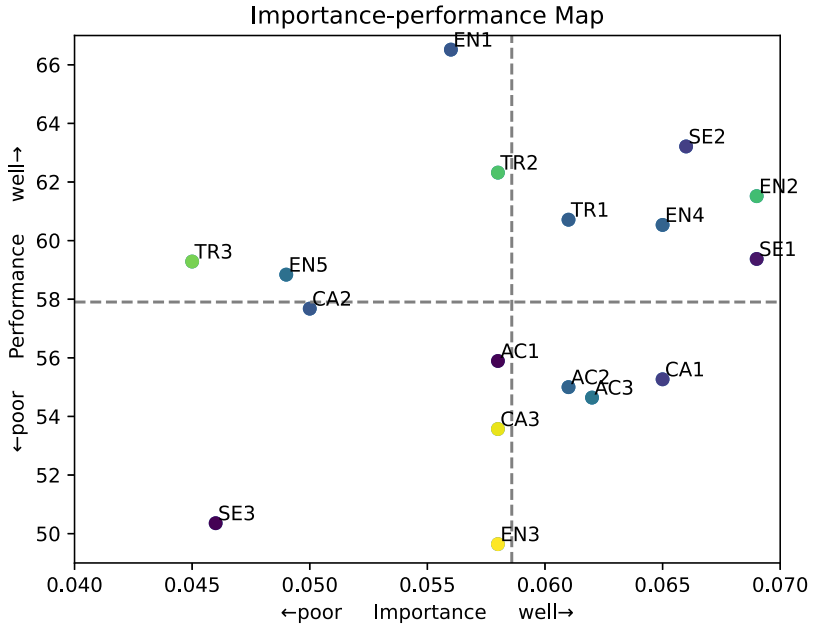

Fig. 3. Importance-performance analysis. Refer to Table 1 for abbreviations.

AC2, AC3 and CA1 are located in the fourth quadrant, representing accommodation price, accommodation distribution and catering services safety and hygiene respectively. These factors are of high importance but low performance, thus requiring focused development. However, if tourists do not require extended stays, the issue of accommodations may not be as pressing. But food safety remains a critical concern that demands attention.

5. Discussion

5.1. Discussion of results

The questionnaire of this study was modified based on the original model, especially in "perceived quality", where involves the service content of Guangzhou HEMC as much as possible. Although the questionnaire was issued in the whole scope of the Guangzhou HEMC and involved tourists from different scenic spots as far as possible, the demographic profile of tourists still showed the characteristics of a sizable cohort, almost up to 50%. This may result in certain issues with specific indicators, however overall it remains acceptable.

Based on the calculation results, it appears that only the two paths leading from customer expectations to customer satisfaction and leading from customer expectations to perceived value fail to meet the hypotheses of the original model. However, Johnson points out that customer expectation has no direct impact on customer satisfaction according to the data analysis using SCSB [89], which shows that the model and method are still reliable. In addition, the path leading from customer complaint to customer loyalty. The expectation model proposed by Parasuraman et al. posits that service quality and customer satisfaction are evaluated through the comparison of "expectations" and "performance" [90]. Therefore, differences in expectations and consumer behaviors may also account for the lack of empirical evidence supporting the relationship between customer expectation and perceived value. The questionnaire survey, however, also possesses inherent limitations. Specifically, the questionnaires distributed in tourist attractions may not necessarily capture the comprehensive sentiments of visitors, and their actual perceptions remain subject to change [91]. In fact, this not only accounts for the disparity in tourists' perception of popular science tourism and the science popular function of Guangzhou HEMC but also reflects the behavioral traits of visitors to Guangzhou HEMC, such as their lack of consumer behavior.

The findings of IPA demonstrate a forward-looking emphasis on the orientation of work. The science popularization resources and services in the university city exhibit commendable performance, which has gone unnoticed by other researchers [45]. Additionally, there exists a certain disparity between the analytical findings and field survey results; hence, further policy measures must be formulated based on the latter. The significance of these items is assessed based on their impact on tourist satisfaction. This does not imply that poor performance or insignificance is acceptable, but rather highlights the importance of meeting tourists' expectations and the variations in their perceptions. In fact, there is a strong spatial clustering of catering and accommodation services in Guangzhou HEMC, as most of these facilities are concentrated in four villages and located at a certain distance from scenic spots, which may contribute to the differences in perception.

5.2. Popular science tourism development in Guangzhou HEMC

Based on the aforementioned findings, the following recommendations are proposed to advance popular science tourism in Guangzhou HEMC.

(1) Enhance the promotion of popular science tourism

There are numerous popular science attractions in Guangzhou HEMC, yet the lack of publicity has resulted in their limited popularity. To address this issue, we can vigorously promote these scenic spots by uploading pictures or videos on social media or video websites and posting posters in urban areas. The publicity strategy should encompass a wealth of popular science resources, convenient transportation, and picturesque surroundings to enhance the appeal of popular science attractions and foster the growth of scientific tourism in Guangzhou HEMC. Additionally, it is imperative to bolster local residents' comprehension of scientific tourism.

(2) Attaching importance to science popularization and introduction of science popularization resources

Guangzhou HEMC should leverage its abundant popular science resources and strong scientific research atmosphere to assume the responsibility of promoting popular science throughout society. It should actively introduce new popular science resources while prioritizing the importance of updating and enriching existing ones, providing a solid foundation for popular science tourism and enhancing its attraction in Guangzhou HEMC. Additionally, the incorporation of clustering effects into popular science resources can facilitate the implementation of price reductions for selected services, thereby establishing high-quality and cost-effective popular science tourism products and services.

(3) Further enhance the infrastructure and service

According to the survey, we have identified unreasonable distribution, inadequate quantity, simplistic design and poor hygiene of public toilets in Guangzhou HEMC. These factors contribute to increased queuing times for tourists and decreased satisfaction levels. Therefore, future adjustments should include rationalizing the layout of public toilets, increasing their number or repairing existing ones, as well as hiring more cleaning personnel to ensure cleanliness. Additionally, the road conditions in Guangzhou HEMC are suboptimal with some roads being narrow and uneven, which may impede tourist travel and necessitate adjustments for improvement. Furthermore, certain visitors have reported insufficient parking availability and traffic congestion during peak holiday periods. To address this issue, Guangzhou HEMC could expand its parking facilities and deploy traffic police to regulate holiday traffic flow. With only two subway stations and limited external transportation routes, it would be beneficial for Guangzhou HEMC to consider expanding its external transit options in the future. Additionally, given that lodging and dining options are concentrated in villages, it is imperative to reinforce oversight of the sanitation and caliber of these services.

5.3. Theoretical contributions

First, the ACSI model has not previously been used in popular science tourism satisfaction studies, and this study attempted to use this model to assess the satisfaction of this specific tourism. Through the results of this study, we came to a conclusion that customer expectation may not correlate to perceived value and customer satisfaction, which is different from current studies achieved [52,53]. Wu came up with an index of 64.26 and 62.78 in his study, which he attributed to the difference between high expectations and low experience [52]. Li et al. also found that the satisfaction index of tourists was only 59.61 and 58.62, which were at a low level, and the path coefficient of customer expectation on perceived value was also relatively low [53]. Therefore, in some cases, expectations may not be necessarily related to perceived value, especially for specific kinds of tourism, and are accompanied by lower satisfaction. Chen even found a negative correlation between customer expectations and perceived value, which she attributed to overpublicity [51]. As a result, reasonable publicity and pricing play a vital role in tourism. Moreover, when studying specific forms of tourism, the satisfaction model used should be carefully considered.

Secondly, we combined the previous tourism evaluation research and popular science evaluation research to construct the questionnaire items of popular science tourism evaluation [46,77], which can provide a certain reference for future popular science tourism satisfaction researches.

5.4. Practical implications

First, this study explores the feasibility of university towns as a popular science tourism destinations. In fact, some Chinese scholars have expressed concern about the potential for islanding in China's university towns in the future [92]. However, popular science tourism serves as a bridge connecting these university towns with cities, facilitating the exchange of knowledge and technology between them, effectively addressing concerns about their isolation.

Moreover, the diversification of the tourism market necessitates higher quality and more sustainable forms of tourism. The exploration of popular science tourism can also offer insights for the sustainable development of tourist attractions and continuously enhance the quality of popular science tourism. This not only signifies a progression in college town tourism but also extends to other forms of tourism.

5.5. Limitations and future work

There have been limited studies on popular science tourism in Guangzhou HEMC, with current research primarily focused on spatial data analysis. However, as tourists are the main participants in such activities, there remains a lack of research from their perspective. This study has partially addressed this gap by examining popular science tourism in Guangzhou HEMC through the lens

of tourist experience evaluation. In the future, additional data mining is necessary to conduct a more comprehensive evaluation of Guangzhou HEMC, in order to advance the development of popular science tourism and establish a tourist-friendly popular science center. Furthermore, discrepancies remain regarding the definition of popular science tourism; thus, it is imperative to further standardize this definition.

6. Conclusions

Based on the data collected from the questionnaire during the field survey, this study utilized the ACSI model to identify key factors influencing tourists' satisfaction with Guangzhou HEMC science popularization tourism. Furthermore, by incorporating the TSI index, the ACSI model was employed to assess the level of tourist satisfaction. Moreover, through constructing an IPA map, this research identified potential areas for future improvement in Guangzhou HEMC science popularization tourism. In summary, the primary findings of this study can be succinctly summarized as follows:

According to the macro ACSI model, all paths align with the assumptions of the original model, except for the two paths originating from customer expectations that lack support. This partially elucidates the significance of pre-publicity in shaping tourism perception. It is noteworthy that among the two paths exhibiting higher path coefficients, namely customer expectations to perceived quality and perceived quality to perception value, the latter path coefficient slightly surpasses, implying that emphasizing on elevating tourists' expectations, enhancing product quality, and establishing reasonable pricing are all pivotal factors since both quality and value serve as crucial determinants of satisfaction. The TSI index in the micro model represents overall satisfaction. After comparing several studies evaluated using this model, it was observed that although the level of tourism satisfaction in Guangzhou HEMC is not particularly high, it still remains competitive.

The results of importance-performance analysis show that the professionalism and service attitudes of the destination's service personnel, as well as popular science resources and safety facilities, and transportation into Guangzhou HEMC all contribute to satisfaction at both the importance and performance levels of excellence. The aspects of internal transportation and parking, human and natural landscapes, and congestion levels demonstrate high satisfaction performance and should be continued. However, there is still room for improvement in the areas of food and beverage safety issues, price of accommodation, and convenience, which are crucial factors for satisfaction but exhibit poor performance. The representation of the price and distribution of food and drink, the sanitary environment, the accommodation environment, and the distribution of infrastructure exhibit subpar performance and limited significance in terms of satisfaction. These aspects can be considered for future enhancement without immediate urgency.

In addition, to ensure the generalizability of the results, we conducted interviews alongside questionnaire distribution in order to comprehend specific demands. By synthesizing the aforementioned findings, we formulated recommendations for the advancement of popular science tourism in Guangzhou HEMC. Furthermore, we also differentiate between several analogous concepts pertaining to science tourism that hold relevance for future research.

Founding

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CRediT authorship contribution statement

Yunpeng Xu: Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Dafang Wu:** Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **Yucheng Zhang:** Methodology, Investigation. **Xiaolan Liang:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Funding acquisition, Formal analysis. **Yuying Zeng:** Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation. **Yihan Chen:** Writing – review & editing, Writing – original draft, Validation. **Xianlan Xie:** Writing – original draft, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data has been uploaded as a supplementary document.

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Appendix A. Supplementary material

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