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A Two-Tuple Linguistic Model for the Smart Scenic Spots Evaluation

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ABSTRACT

The evaluation on the level of smart scenic spots is crucial in the planning and development of smart tourism destinations. However, existing evaluation approaches for smart scenic spots lack scientific rigor and practical applicability. To address this issue, this study proposes a comprehensive evaluation method that combines qualitative analysis and quantitative calculation to establish a weighted index system for assessing the level of smart scenic spots. The approach utilizes a fuzzy comprehensive evaluation model, integrating linear weighted comprehensive evaluation methods, fuzzy mathematics, and the concept of two-tuple. Moreover, the concept of level eigenvalue is introduced to facilitate the evaluation of smart scenic spots. The proposed two-tuple model and evaluation method demonstrate strong operability, applicability, and promotional potential, as evidenced through example calculations and analysis.

KEYWORDS

Evaluation on the Smart Level, Fuzzy Comprehensive Evaluation, Smart Scenic Spots, Two-Tuple Linguistic

INTRODUCTION

Smart scenic spots play a crucial role in serving tourists and promoting sustainable development in scenic areas; evaluating these spots is essential for the successful planning and development of smart tourism. Although the term *smart scenic spot* is less common outside China, it has a significant historical background that has captured considerable academic attention regarding the technical advancements and applications of smart technology in scenic areas (Dimitrios Buhalis, 2008; Owaied et al., 2011; Borràs et al., 2014; Taehyee & Namho, 2019). Studies in China have primarily concentrated on the intrinsic concept of smart scenic spots, the development of smart tourism systems, the tourists' spatial behaviors, and investigations into the willingness of using the smart tourism systems (Dang et al., 2011; Ruan, 2017, Li et al., 2019; Xu & Huang, 2018). However, there is a noticeable lack of research on evaluating the smart level of these sites. Such evaluations aim to identify the factors contributing to the development of smart scenic spots, establish a weighted index system, and calculate corresponding grades. For instance, Tang (2014) developed an index system encompassing management, service, marketing, and support, and employed the analytic hierarchy process (AHP) to assign weights to the indices. Through a multi-factor comprehensive evaluation method, Tang

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conducted an empirical study on Nanjing Zhongshan Mausoleum (Tang, 2014). Similarly, Li and Shi (2017) constructed an index system for Lanzhou smart scenic spot, considering dimensions like environmental monitoring, intelligent security, energy management, traffic management, scenic spots public release platform, and intelligent management service. They used the analytic hierarchy process to weigh the indices, established an evaluation model, and proposed policy suggestions for the Lanzhou smart scenic spot (Li & Shi., 2017). Pan (2018) and Chen et al. (2019) developed a concise evaluation system that includes infrastructure, service smartness, marketing smartness, and management smartness, the CRITIC and AHP methods are employed to determine index weights and extended the application to evaluate the smart level of scenic spots above 4A in Jiangsu province. Moreover, Guo et al. (2022) utilized the entropy method to assess navigation, guide, and shopping in China's first and second batches of smart scenic cities above 3A, providing a crucial evaluation of their smart level.

Many researchers have treated the evaluation of smart level and level of smart scenic spots as interchangeable problems to solve. In this context, the comprehensive evaluation value of the smart scenic spots is obtained, and the associated smart level is determined by comparing the value against a predefined threshold. However, it is important to recognize that, conceptually and methodologically, the ranking evaluation of smart scenic spots differs from the ranking evaluation of the degree of smart. To address this issue and enhance the quality and credibility of evaluation on the smart level of scenic spots, this paper clearly defines the smart level evaluation on scenic spots. Additionally, a general model for conducting an evaluation on the smart level is developed with a rational, mathematical methodology. By differentiating the two types of evaluations, this approach aims to refine the assessment process and ensure accurate results for evaluating the smart level of scenic spots.

As a theoretical application piece, this paper incorporates the two-tuple linguistic mode with the evaluation of smart scenic spots. Therefore, our research differs in two ways from previous methods, which are both the contributions of this article and the core points that need to be demonstrated. First, in the existing literature, the old-fashioned approach to scenic spot evaluations mainly focused on the AHP, Delphi method, entropy method, and fuzzy comprehensive evaluation. Many of these methodologies rank scenic spot smartness as the grading of the smartness. Specifically, after obtaining a comprehensive evaluation score for a smart scenic spot, its smart level will be determined according to the grade thresholds, assessing whether the overall smartness score meets the criterion. A major flaw of these methods is that they can only judge the hierarchical level between objectives and cannot weigh the pros and cons of multiple objectives at the same level. With the help of the two-tuple linguistic model, ranking within the level becomes possible for smart scenic spot evaluations.

Second, in contrast to the two-type fuzzy sets, which obtain the advantages in the hierarchical structure analysis, the two-tuple linguistic model not only captures preferences with quantitative representations during decision-making, but also extracts information behind the uncertainty of language using and terminology in evaluations. It mitigates information loss and hence builds a more accurate and robust result, and our conclusions support this point of view.

EVALUATING THE SMART LEVEL OF SCENIC SPOTS

This study implemented a comprehensive methodology to ensure the applicability of smart level evaluation. First, a weighted index system was constructed, considering various factors contributing to scenic spots' smartness. Next, the grade of smartness was calculated using fuzzy comprehensive evaluation, which allows for a more nuanced and precise assessment. To optimize the evaluation results further, the study introduced the concepts of level characteristic value and two-tuple linguistic. These additions not only aid in determining the smart level of a scenic spot but also enable the ranking of smart degrees within each level. This approach significantly enhances the applicability of evaluating and comparing different smart scenic spots. By combining these elements, the methodology presented in this paper ensures a more accurate, reliable, and practical evaluation of the smart level of scenic spots. This comprehensive approach is well-suited for guiding the development and improvement of smart scenic spots, promoting sustainability, and offering a valuable tool for decision-makers in the tourism industry.

Indices on Evaluating the Smart Level of Scenic Spots

Following the "Beijing Smart Scenic Spot Construction Guidelines (for Trial Implementation)" (2012), "Fujian Province Classification and Accreditation for Smart Tourism Destinations" (2022), and other relevant literature (Tang, 2014; Wang et al., 2015; Li & Shi, 2017; Chen et al., 2019), we built the index system of smart scenic spots evaluation by expert interview and field research. The system is organized into three levels. The primary level has four evaluation indicators: smart management (O_1), smart services (O_2), smart marketing (O_3), and smart support (O_4). The secondary level encompasses nine indicators, including intelligent security (O_{11}) and environmental monitoring (O_{12}). The tertiary level consists of 30 indicators, such as the scope of video surveillance coverage (O_{111}) and the development level of emergency response systems (O_{112}). Details are shown in Table 1.

Standards for Smart Scenic Spots Level and Weights of the Index System

Standards for Smart Scenic Spots Level

The smart level of kth scenic spot is represented by e_k (k = 1, 2, . . ., h) with the partial order $e_1 > e_2 > \ldots e_h$, it follows that the smart level of kth scenic spot is superior to the (k + 1)th one, this specific partial order gives the level set of smart scenic spots evaluation such that $V = \left\{e_1, e_2, \ldots e_n\right\}$. Moreover, the ground bases for us to construct smart level are "Beijing Smart Scenic Spot Construction Guidelines (for Trial Implementation)" (2012), "Fujian Province Classification and Accreditation for Smart Tourism Destinations" (2022), and Tang (2014), and according to the evaluation standards and grade thresholds in each smart scenic spot, the smart level is set to $h = 5$, and e_1–e_5 indicate levels I–V, respectively. Specifically, e_1 denotes a very high smart level, e_2 denotes the high one, e_3 denotes the ordinary one, e_4 denotes the poor one, while e_5 is the worst-case scenario. The details can be seen in Table 2.

Weights of the Index System

On the data and level indices of smart scenic spots, we gauge the impact on the benefits of these spots and the challenges of their implementation. We sought insights from industry experts and employed the AHP method. Using a 1–9 scale, we pairwise assessed the relative significance of the smart level indices. Based on these comparisons, we formulated judgment matrices for each tier, utilized Excel to determine the maximum eigenvalue and its associated eigenvector, and performed a consistency check. In the end, we established the weights for the index system of the smart scenic spots, details are shown in Table 1.

The Grade Membership Function of the Evaluation Indices

The evaluation indices can be divided into two categories: the quantitative one and the qualitative one.

The Membership Degree of the Qualitative Evaluation Indices

On the actual characteristics and requirements of the smart scenic spots, the grade membership function of the qualitative evaluation indices $O_{ijl}\left(l = 1, 2, \ldots L_{ij}\right)$ of smart scenic spot $A_t\left(t = 1, 2, \ldots N\right)$ can be defined as follows:

Table 1. Evaluation indices and weight of smart scenic spots for the goal: Comprehensive development level of smart scenic spots

System	Weight	Element	Weight	Indicator	Weight
Smart management (O_1)	0.30	Intelligent security (O_{11})	0.36	Video surveillance coverage (O_{111})	0.46
				Emergency response system construction level (O_{112})	0.33
				Fully functional command and control center (O_{113})	0.21
		Environmental monitoring (O_{12})	0.39	Real-time statistics and analysis of tourist flow (O_{121})	0.45
				Environment monitoring content (O_{122})	0.23
				Modern scientific management level of landscape resources (O_{123})	0.32
		Daily operations (O_{13})	0.25	Proficiency in professional financial management software (O_{131})	0.39
				Automatic office function (O_{132})	0.42
				Content of resource management (O_{133})	0.19
Smart service (O_2)	0.40	Portal information (O_{21})	0.33	Portal website establishment and operation (O_{211})	0.43
				Reasonableness of touch screen multimedia terminal (O_{212})	0.28
				Tourism information release form (O_{213})	0.29
		Interactive Experience (O_{22})	0.67	Electronic ticket form (O_{221})	0.11
				Comprehensive functions of electronic access control system (O_{222})	0.08
				Coverage of digital virtual scenic area (O_{223})	0.07
				Authenticity and convenience of virtual travel (O_{224})	0.19
				Coverage of self-guided tour system (O_{225})	0.23
				Customized service of personalized tourist line (O_{226})	0.13
				Multimedia display (O_{227})	0.12
				Construction of tourist complaints service platform (O_{228})	0.07
Smart marketing (O_3)	0.17	E-commerce (O_{31})	0.67	Sales channels of tourism products (O_{311})	0.43
				Payment (O_{312})	0.26
				New promotion for tourism products (O_{313})	0.31
		Brand promotion (O_{32})	0.33	Online communication (O_{321})	0.42
				Development of derivative tourism product (O_{322})	0.36
				Monitoring of tourism public opinion (O_{323})	0.22
Smart support (O_4)	0.13	Communication network (O_{41})	0.5	Coverage of wireless communication network (O_{411})	0.5
				Coverage of wireless broadband (O_{412})	0.5
		Planning (O_{42})	0.5	Construction planning of smart tourism scenic spots (O_{421})	0.5
				Input of security (O_{422})	0.5

$$\mu_{tijlk} = \begin{cases} 1 & O_{ijl} \ of \ A_t \ satisfies \ e_k \\ 0 & otherwise \end{cases} \tag{1}$$

If the index $O_{ijl}\left(l = 1,2,...L_{ij}\right)$ of A_t satisfies the benchmark value of e_k, then the grade membership function μ_{tijlk} is equal to 1. On the contrary, if the index O_{ijl} does not meet the benchmark

Table 2. Reference values and criteria of smart scenic spots

Evaluation Indices	Evaluation Rating				
	e_1 I	e_2 II	e_3 III	e_4 IV	e_5 V
Surveillance cover rate	Covering all scenic spots, full monitoring on important spots, tourist centralized location and areas with frequent accidents	Covering 80% of scenic spots, key monitoring on important spots, tourist centralized location and areas with frequent accidents	Covering more than 50% of scenic spots, effective monitoring on important spots, tourist centralized location and areas with frequent accidents	Covering more than 30% of scenic spots, monitoring on tourist centralized location and areas with frequent accidents	Covering Less than 30% of scenic spots
Emergency response system construction level	Very high, travel consultation and complaints being received in time according to the emergency plan with modern communication tools and calling system	High, providing comprehensive command and coordinate rescue for tourism emergencies according to the emergency plan	Ordinary, broadcast being immediately converted to emergency use while it is under the unified control of the control center of the scenic spot	Poor, broadcast only	Very poor, no emergency response system
Fully functional command and control center	Very highly functional, in addition to emergency command, control center can acquire comprehensive tourism information from municipal and district, and release them quickly and effectively	Highly functional, effective organization, coordination, management and control of emergency resource	Ordinary, conducting personnel and vehicle command and dispatch	Not functional, only conducting personnel command and dispatch	Very poorly functional, no command and control center
Real-time statistics and analysis of tourist flow	Very high, real-time statistics and monitoring the entrance and exit and the total number of tourists with automatic alarm mechanism for visitor limit	High, real-time statistics and monitoring the entrance and exit, the total number of tourists and tourist centralized location	Ordinary, monitoring tourist flow of entrance and exit and real-time statistics of total tourist number	Poor, tourist flow statistics management of entrance and exit	Very poor, only entrance tourist flow statistics management
Environment monitoring content (quantitative indices)	Environment monitoring content is divided into six categories: natural landscape, cultural landscape, atmospheric environment, water environment, biological environment and noise				
	≥5, with five or more items above	4-with 4 items above	3-with 3 items above	2-with 2 items above	1-with 1 item above
Modern scientific management level of landscape resources	Very high, information and digitization measurement control, record, preservation, repair, maintenance, search, analysis, and public display with modern scientific management tools	High, information and digitization measurement control, record, preservation, repair, maintenance, search, and analysis with modern scientific management tools	Ordinary, information and digitization measurement control, record, preservation, repair, and maintenance with modern scientific management tools	Poor, information and digitization measurement control and record with modern scientific management tools	Very poor, without any modern scientific management tools
Proficiency in professional financial management software	Very high, not only the skilled usage of methods for element management, but also innovation software functions combined with the actual enterprise	High, using financial forecasting, decision-making, budgeting, control, and other methods to manage the corresponding elements	Ordinary, management of assets, financing, investment, operating income, etc.	Poor, only management of assets and operating income	Very poor, playing a relatively small role

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Table 2. Continued

Evaluation Indices	Evaluation Rating				
	e_1 I	e_2 II	e_3 III	e_4 IV	e_5 V
Automatic office content	Process management, E-mail, document management, document transmission, approval management, work calendar, personnel dynamic display, financial settlement management, announcement, news, notice, personal information maintenance, meeting management, attendance management				
	≥ 10, with ten or more items above	≥ 8, with7–9 items above	≥ 6, with 5–6 items above	≥ 4, with 3–4 items above	≥ 2, with 1–2 items above
Content of resource management	Including commercial resources deployment, shop management, operating supervision, contract management, property standards, etc.				
	5, with 5 items above	4, with 4 items above	3, with 3 items above	2, with 2 items above	1, only with 1 item above
Portal website establishment and operation	Very well, rich content and functions, providing self-service tour guide software, audio, video, maps and other download services	Well, complete functions and strong interactivity, building an official microblog with links and multiple language services	Ordinary, with basic functions such as tourist route recommendation and travel planning, promotion services, traffic navigation	Poor, only basic information browsing and query	Very poor, only basic information browsing
Touch-screen multimedia terminal	Quite reasonable, with adequate quantity of touch-screen multimedia terminal, reasonable layout and functionalities	Reasonable, with adequate quantity of touch-screen multimedia terminal and reasonable layout	Ordinary with adequate quantity of touch-screen multimedia terminal	Unreasonable, only with some touch-screen multimedia terminal	Very unreasonable, only small amount of touch-screen multimedia terminal
Tourism information release form	Tourism information release through LED screen, self-service guided tour terminal, touch-screen multimedia terminal, SMS, MMS, public broadcasting				
	5-with 5 items above	4-with 4 items above	3-with 3 items above	2-with 2 items above	1-with 1 item above
Electronic ticket form (quantitative indices)	≥4, in addition to paper (printed with barcode or QR code), SMS(MMS) and RFID, other forms of electronic ticket being used	3-with paper (printed with barcode or QR code), SMS(MMS) and RFID	2-with paper (printed with barcode or QR code) and SMS(MMS)	1-only paper (printed with barcode or QR code)	0-no electronic ticket, only traditional printed hand-torn ticket
Functionalities of electronic access control system	Electronic access control system has all access tickets control management such as ticket selling, ticket checking, inquiry, summary, statistics and statement, as well as the omni-directional real-time monitoring and management				
	Very comprehensive, realizing automatic identification ticket, ticket checking information network and remote query	Comprehensive, realizing the automatic identification and ticket checking information network	Ordinary, with electronic access control, automatic identification and ticket checking	Incomplete, having handheld mobile terminal equipment and automatic identification and ticket checking	Very incomplete, no electronic access control system
Coverage of virtual scenic spot	Virtual tourism refers to the use of 3D panoramic real scene mixed reality technology, 3D modeling and simulation technology, 360-degree real scene photos or videos and other technologies to build a virtual scenic spot to achieve virtual tourism and enhance the public attributes of the scenic spot				
	≥ 70%	≥ 50%	≥30%	≥ 20%	≥ 10%
Authenticity and convenience of virtual travel	Very high, adopting 3D panoramic real scene mixed with reality technology, clicking any point on the ground to real-time scene switching, and sharing links of tour content or Weibo forwarding	High, using the computer graphics image technology to construct the 3D panoramic space based on the images obtained from the real scene	Ordinary, adopting virtual 3D modeling and simulation technology to reproduce real scenes	Low, only using 360-degree real scene photos or videos	Very low, failed to implement virtual travelling

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Table 2. Continued

Evaluation Indices	Evaluation Rating				
	e_1 **I**	e_2 **II**	e_3 **III**	e_4 **IV**	e_5 **V**
Coverage of self-guided tour system	● Self-guided tour is popular. ● Scenic spots should establish a modern self-service tour guide system based on wireless communication, global positioning, mobile Internet, Internet of things and other technologies. ● The hardware equipment can display the tourist map, support wireless Internet as well as global positioning system, complete the self-guided tour explanation.				
	Achieve 100%	≥ 80%	≥ 50%	≥ 30%	< 30%
Customized service of personalized tourist line	Very high, not only supporting a variety of field and advance customization, but also downloading mobile terminal applications and customizing anytime and anywhere	High, supporting portal website, on-site touch-screen customization and the electronic guide tool provided by the scenic spot for the entire area	Ordinary, with advance customization, on-site touch-screen multimedia terminal set up in the scenic spot for customization	Low, customizing the travel routes on portal website	Very low, paper guidebooks provided only
Multimedia display	Need to use multimedia display tools, including arc curtain system, circular screen system, ball screen system, three-dimensional projection system, digital audio system, VR system, spherical projection system, desktop projection system, digital sand table system, virtual pages system, interactive game system, electronic signature, and electronic survey system				
	≥ 8, using 8 or more tools above	≥ 6, using 6 to 7 tools above	≥ 4, using 4 to 5 tools above	≥ 2, using 2 to 3 tools above	1, only using 1 tool above
Construction of tourist complaints service platform	Very high, supporting complaint forms like service centers, telephone and network, touch-screen multimedia terminals online messages, and being connected with the 12301-tourism hotline platform	High, supporting complaint forms like service centers, telephone and network, touch-screen multimedia terminals online messages	Ordinary supporting complaint forms like service centers, telephone, and network	Low, supporting complaint forms like service centers and telephone	Very low, only supporting telephone complaint
Sales channels of tickets and other tourism products	Scenic spot tickets and other tourism products are no longer limited to on-site sales, such as: offline travel agency group distribution, official website, QR code, WeChat direct sales and Taobao, Qunar, Ctrip, Tuniu and other major tourism e-commerce distribution				
	≥ 5, Supporting all forms of direct selling and distribution, and innovating sales channels	4, Supporting field sales, offline travelling agency group distribution, official website, QR code, WeChat and Taobao direct sales, Qunar, Ctrip, Tuniu and other major tourism e-commerce distribution	3, Supporting field sales, offline travelling agency group distribution, official website, QR code, and WeChat direct sales	2, Supporting field sales, offline travelling agency group distribution	1, Supporting field sales only
Payment	It is divided into cash payment, POS card payment, wire transfer, bank transfer, mobile payment, and online payment				
	≥ 5, supporting five or more methods above	4, supporting four methods above	3, supporting three methods above	2, supporting two methods above	1, supporting one method above
New promotion for tourism products	At present, new promotions include network group-buying, travel consumption coupons, complimentary e-ticket, e-card and travel full exchange				
	≥ 5, using 5 and more promotions above	4, using 4 promotions above	3, using 3 promotions above	2, using 2 promotions above	1, using 1 promotion above

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Table 2. Continued

Evaluation Indices	Evaluation Rating				
	e_1 I	e_2 II	e_3 III	e_4 IV	e_5 V
Online communication platform	Tourism forum, official website, official microblog, official WeChat, mobile client software, QQ, MSN, E-mail				
	≥ 5, using 5 and more platforms above	4, using 4 platforms above	3, using 3 platforms above	2, using 2 platforms above	1, using 1 platform above
Development of derivative tourism product	Very high, the development of physical and service derivative products, and combining with tourism marketing for commercial operation	High, with physical products and developing service derivatives, such as compiling tourism stories and game software related to scenic spots	Ordinary, developing a certain number of products and service derivatives, and having a certain popularity among tourists	Low, developing a small number of physical and service derivatives	Very low, only developing a small number of physical derivatives
Monitoring of tourism public opinion	Yes				No
Coverage of wireless communication network	Achieving 100%, receiving mobile phone signals anywhere	More than 80% of the area receiving mobile phone signals	More than 50% of the area receiving mobile phone signals	More than 30% of the area receiving mobile phone signals	Less than 30% of the area receiving mobile phone signals
Coverage of wireless broadband	100% WLAN covering the whole scenic area basically	≥ 80% WLAN covering 80% of scenic area WLAN	≥ 50% WLAN covering the entrance and exit of scenic spots, tourist service center and tourist concentrated areas	≥ 30% WLAN only covering the entrance and exit of scenic spots and tourist service center	< 30% WLAN only covering the entrance of scenic spots and tourist service center
Construction plan of smart scenic spots	Very high, establishing a comprehensive construction plan for smart scenic spot, and has passed the evaluation and certification	High, establishing a detailed and professional construction plan of smart scenic spot	Ordinary, establishing a relatively detailed and professional construction plan of scenic spot	Low, only part of the smart scenic spot has construction plan	Very low, only relevant schemes for smart scenic spot but no construction plan
Input of security	Very high, with high investment of capital, manpower and material resources, other factors to support the construction of the scenic spot	High, meeting the needs of smart scenic spot construction with investment of capital, manpower and material resources	Ordinary, meeting the needs of smart scenic spot construction with capital input and relevant personnel responsible	Low, only the majority part of the budget for the construction of smart scenic spot	Very low, only a small part of the budget for construction of smart scenic spot

value of e_k, then the grade membership function μ_{tijlk} is 0. In the above equation, μ_{tijlk} indicates the membership of the *l*th three-level evaluation index (qualitative) O_{ijl} of the *j*th two-level evaluation index $O_{ij}\left(j = 1, 2, \ldots n_i\right)$ of the *i*th first-level evaluation index $O_i\left(i = 1, 2, \ldots m\right)$ that belongs to the *kth* smart level e_k. Considering three smart scenic spots, denoted as A_1, A_2, and $A_3\left(N = 3\right)$, and based on the information provided in Table 1, the associated values and parameters are:

$$m = 4, n_1 = 3, n_2 = 2, n_3 = 2,$$
$$L_{11} = 3, L_{12} = 3, L_{13} = 3, L_{21} = 3, L_{22} = 8, L_{31} = 3, L_{32} = 3, L_{41} = 2, L_{42} = 2$$

Moreover, Equation 1 represents the hierarchical membership function for the three-level evaluation indices, and it can also be applied to determine the grade membership functions of two-level and first-level qualitative evaluation indicators. This methodology allows us to assess the smartness of scenic spots across multiple levels and indicators, providing a comprehensive and effective evaluation approach.

The Membership Function of the Quantitative Evaluation Indices

To obtain an efficient evaluation index system, the membership function of the quantitative evaluation index O_{ijl} of smart scenic spot A_t can be selected as follows:

$$\mu_{tijl1} = \begin{cases} 1 & \left(y_{tijl} \geq a_{ijl1}\right) \\ \dfrac{y_{tijl}}{a_{ijl1}} & \left(0 \leq y_{tijl} < a_{ijl1}\right) \end{cases} \tag{2}$$

$$\mu_{tijlk} = \begin{cases} \dfrac{a_{ijl,k-1}}{y_{tijl}} & \left(y_{tijl} \geq a_{ijl,k-1}\right) \\ 1 & \left(a_{ijlk} \leq y_{tijl} < a_{ijl,k-1}\right) \quad \left(k = 2,3,4\right) \\ \dfrac{y_{tijl}}{a_{ijlk}} & \left(0 \leq y_{tijl} < a_{ijlk}\right) \end{cases} \tag{3}$$

$$\mu_{tijl5} = \begin{cases} \dfrac{a_{ijl4}}{y_{tijl}} & \left(y_{tijl} \geq a_{ijl4}\right) \\ 1 & \left(a_{ijl5} \leq y_{tijl} < a_{ijl4}\right) \\ \dfrac{y_{tijl}}{a_{ijl5}} & \left(0 \leq y_{tijl} < a_{ijl5}\right) \end{cases} \tag{4}$$

In the preceding functions, y_{tijl} represents the value of the *l*th three-level (quantitative) evaluation index O_{ijl} of smart scenic spot A_t, a_{ijlk} denotes that O_{ijl} belongs to level $e_k\left(k = 1,2,...h\right)$ where $h = 5$ in such case (similarly for other cases). Moreover, O_{tijlk} indicates that at smart scenic spot A_t, the *l*th three-level evaluation index (quantitative) O_{ijl} of the *j*th two-level evaluation index $O_{ij}\left(j = 1,2,...,n_j\right)$ of the *i*th first-level evaluation index $O_i\left(i = 1,2,...,m\right)$ is assigned to *kth* smart level e_k.

When the grade reference value (Or division value) of the quantitative evaluation indices is the same or falls within the same interval, the level membership function of the quantitative evaluation index O_{ijl} of smart scenic spot A_t can be selected as follows:

$$\mu_{tijlk} \begin{cases} 1 & O_{ijl} \ of \ A_t \ satisfies \ e_k \\ 0 & otherwise \end{cases} \tag{5}$$

The above approach is also capable of determining the membership functions of second-level and first-level qualitative evaluation indicators. By using these membership functions, the smartness level of scenic spot A_t can be accurately assessed based on the quantitative evaluation indices and their relationship to the established benchmark values for each level.

Comprehensive Model and Two-Tuple Linguistic Method for Evaluating the Smart Level

Based on the characteristics of the smart scenic spots, the membership function μ_{tijlk} for the evaluation index O_{ijl} can be calculated using Equations 1–5 with both qualitative and quantitative evaluation indices. This calculation results in the membership matrix $\hat{\mu}_{tij} = \left(\mu_{tijlk}\right)_{L_{ij} \times h}$, which provides the basic data for the smart level evaluation.

Similarly, the weights of the first, second, and third level evaluation indices presented in Table 1 can be expressed as the following weight vectors:

$$\omega = \left(\omega_1, \omega_2, \ldots, \omega_m\right)^T \cdot \omega_i = \left(\omega_{i1}, \omega_{i2}, \ldots, \omega_{in_i}\right)^T \cdot \omega_{ij} = \left(\omega_{ij1}, \omega_{ij2}, \ldots, \omega_{ijL_{ij}}\right)^T$$

Fuzzy Comprehensive Model of Smart Scenic Spots Evaluation

Our fuzzy comprehensive evaluation model based on the fuzzy linear weighted comprehensive evaluation method. This model is designed to meet the inherent requirements of evaluation on the smart level and its three-layer evaluation index structure characteristics. To calculate the comprehensive membership degree of smart scenic spot A_t with respect to the three-level evaluation index O_{ijl} for level e_k, the fuzzy linear weighted comprehensive evaluation method is employed. The calculation is as follows:

$$u_{tijk} = \frac{\omega_{ij}^T \mu_{tijk}}{\sum_{k=1}^{h} \omega_{ij}^T \mu_{tijk}} \qquad \left(k = 1, 2, \ldots, h\right) \tag{6}$$

In the preceding equation, $\hat{\mu}_{tijk} = \left(\mu_{tij1k}, \mu_{tij2k}, \ldots, \mu_{tijLijk}\right)^T$ represents the *kth* column vector of μ_{tij} in the membership matrix. By arranging these column vectors, the comprehensive membership vector u_{ij} of smart scenic spot A_t for all levels e_k can be obtained as $\hat{u}_{tij} = \left(u_{tijk}\right)_{1 \times h}$. By using the comprehensive membership vector, the membership matrix $\hat{\mu}_{ti} = \left(\mu_{tijk}\right)_{n_i \times h}$ can further be derived for the two-level evaluation indices of A_t.

The same model can determine the comprehensive membership vector and membership matrix for the second-level and first-level evaluation indices. In the general evaluation on the smart level, the principle of maximum membership is commonly applied. This means that the smart scenic spot is rated according to the level of membership it belongs to. However, relying solely on the principle of maximum membership can be unreasonable at times. To address this, we introduce the concept of level eigenvalue (Li, 2023).

Decision Value of the Smart Level

The subscript *k* of the intelligence level e_k is called the level variable; therefore, the level characteristic value of the smart scenic spot A_t can be defined as:

$$v_t = \left(1,2,\ldots,h\right)\left(\hat{u}_t\right)^T = \sum_{k=1}^{h} k u_{tk} \quad (7)$$

Note that $u_{tk} \in \left[0,1\right]$ and $\sum_{k=1}^{h} u_{tk} = 1$, then there is:

$$1 = \sum_{k=1}^{h} u_{tk} \le \sum_{k=1}^{h} k u_{tk} \le \sum_{k=1}^{h} h u_{tk} = h$$

Indeed, as mentioned in Equation 7, the level eigenvalues $\left(v_t\right)$ of smart scenic spot A_t provides a dimensionless quantity indicator that lies between the 1st level $\left(e_1\right)$ and the *h*th level $\left(e_h\right)$. The level eigenvalues convey two critical pieces of information: the comprehensive membership degree and the scenic spot smart level (level location). The value $\left[v_t\right]$, represented as the maximum integer not greater than v_t, is used to determine the smart level of A_t. If $\left[v_t\right]$ equals *q*, it indicates that A_t is at the *q*th degree of smart level. Obtaining the maximum integer value from the level eigenvalues v_t is generally considered more comprehensive and objective than relying solely on the principle of maximum membership. However, there are some limitations in this approach. Different levels of eigenvalues may yield the same maximum integer value, leading to some unreasonable evaluations of the smart level of scenic spots. Additionally, this method may fail to clearly distinguish the difference in the degree of smart construction among the scenic spots (Liu & Li, 2016).

To address these challenges and ensure a more accurate and nuanced evaluation of the smart level of each scenic spot, our paper introduces the concept of two-tuple linguistic (Yu et al., 2018; Yu et al., 2016; Herrera & Martinez, 2000; Martinez & Herrera, 2012; Yu & Li, 2022), aiming to refine the assessment process and enhance the distinction between the smart levels of different smart scenic spots. By incorporating the two-tuple linguistic method, we aim to provide a more robust and valuable evaluation on the smart level, considering both the comprehensive membership degree and the variations among smart scenic spots.

Two-Tuple Linguistic Method for the Evaluation of Smart Level

If the level eigenvalue v_t of smart scenic spot A_t is met:

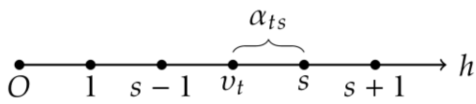
$$s - 0.5 \le v_t < s + 0.5 \quad (8)$$

then the smartness rating of A_t is the *s*th level $\left(e_s\right)$.

To depict the difference degree of smart level of different smart scenic spots within the same level, deviation value between level eigenvalue and its corresponding smart level s (subscript s of level e_s) is denoted as $\alpha_{ts} = v_t - s$ (see Figure 1). Obviously, $-0.5 \le \alpha_{ts} < 0.5$.

The basic idea of two-tuple linguistic method for the evaluation on the smart level of smart scenic spots as follows. First, level eigenvalue v_t of smart scenic spot A_t is denoted

Figure 1. Relation between two-tuple linguistic and grade eigenvalue



as a two-element ordered group $\left(e_s,\alpha_{ts}\right)$, and e_s is the evaluated smart level of A_t, while α_{ts} expresses the deviation value of v_t and its smart level $s,\alpha_{ts}\in\left[-0.5,0.5\right)$. Second, by assessing the smart level of scenic spot A_t — given the size of e_s in $\left(e_s,\alpha_{ts}\right)$, it adjusts and determines the relative difference of the smart scenic spots (that is, determines the priority of the smart scenic spots within a smart level). Obviously, α_{ts} serves as a regulatory signal in the smartness grade rating, implying whether the smart level s is larger or smaller than v_t. Therefore, we call $\left(e_s,\alpha_{ts}\right)$ the two-tuple linguistic pair, and α_{ts} is semantic symbol. To facilitate the computation of the two-tuple linguistic evaluation on the smart level, the size of the two-tuple is specified as follows:

1. If $e_s > e_d\left(s<d\right),\left(e_s,\alpha_{ts}\right)>\left(e_d,\alpha_{rd}\right)$, the smart level of scenic spot A_t is higher than that of A_r, that is $\left(e_s,\alpha_{ts}\right)$ and $\left(e_d,\alpha_{rd}\right)$ are the two-tuple linguistic of level eigenvalue v_t and v_r of smart scenic spots A_t and A_r.
2. If $e_s = e_d(s=d)$, the smart level of scenic spots A_t and A_r is the same, they can be adjusted according to the linguistic symbol to determine the degree of difference. The specific measures are as follows:
   a. If $\alpha_{ts}=\alpha_{rd},\left(e_s,\alpha_{ts}\right)=\left(e_d,\alpha_{rd}\right)$, A_t and A_r have exactly the same degree of smartness.
   b. If $\alpha_{ts}>\alpha_{rd},\left(e_s,\alpha_{ts}\right)<\left(e_d,\alpha_{rd}\right)$, the smart degree of A_t is inferior to A_r (although they are at the same grade).
   c. If $\alpha_{ts}<\alpha_{rd},\left(e_s,\alpha_{ts}\right)>\left(e_d,\alpha_{rd}\right)$, A_t has more smart grade than A_r, A_t is hence ranked before A_r. Obviously, the preceding two-tuple linguistic ranking method not only assesses the smart level of each scenic spot but distinguishes the difference degree of the smartness within same smart level.

EMPIRICAL ANALYSIS OF SMART SCENIC SPOT EVALUATION

Three national 5A scenic spots in Fujian Province, denoted by A_1, A_2 and A_3, were selected as the evaluation objects or samples for smartness evaluation. The three scenic spots began their smart tourism construction in year 2012, 2013, and 2003, respectively. They have achieved varying degrees of success in intelligent ticketing, transportation, intelligent resource management, intelligent service, precise marketing, and office automation. We obtained the smart level evaluation in the three smart scenic spots (see Table 3).

According to Equations 1–5 and Table 3, the hierarchical membership matrix of smart scenic spot A_1 with respect to the three-level evaluation indices can be calculated, the results are as follows:

Table 3. Smart level index and evaluation index values of three smart scenic spots

System	Element	Index	Xiamen Gulangyu Island A_1	Fuzhou San-Fang Qi-Xiang A_2	Wuyi Mount A_3
Management	Intelligent security	Video surveillance coverage	85%	70%	80%
		Emergency response system construction level	High	Ordinary	High
		Functional comprehensiveness for command- and-control center	Comprehensive	Comprehensive	Very comprehensive
	Environment monitoring	Real-time statistics and analysis of tourist flow	High	Low	Very high
		Environment monitoring content	6	2	6
		Modern scientific management level of landscape resources	High	Low	High
	Daily operations	Proficiency in professional financial management software	Proficient	Ordinary	Ordinary
		Automatic office function	12	10	10
R		Content of resource management	5	5	4
Service	Portal information	Portal website establishment and operation	Ordinary	Ordinary	High
		Reasonableness of touch-screen multimedia terminal	Low	Low	Ordinary
		Tourism information release form	5	5	5
	Interactive experience	Electronic ticket form	3	3	4
		Comprehensive functions of electronic access control system	Very comprehensive	Not very comprehensive	Very comprehensive
		Coverage of digital virtual scenic area	35%	30%	40%
		Authenticity and convenience of virtual travel	Ordinary	Low	Ordinary
		Coverage of self-guided tour system	85%	70%	80%
		Customized service of personalized tourist line	Ordinary	Ordinary	Ordinary
		Multimedia display	7	4	6
		Construction level of tourist interaction and complaint linkage service platform	Ordinary	Low	Ordinary

continued on following page

Table 3. Continued

System	Element	Index	Xiamen Gulangyu Island A_1	Fuzhou San-Fang Qi-Xiang A_2	Wuyi Mount A_3
Marketing	E-commerce	Sales channels of tickets and other tourism products	6	5	7
		Payment	6	6	6
		New promotion for tourism products	3	3	5
	Brand promotion	Online communication platform	4	4	4
		Development of derivative tourism product	Low	Low	High
		Monitoring of tourism public opinion	Y	Y	Y
Supporting	Communication network	Coverage of wireless communication network	100%	100%	90%
		Coverage of wireless broadband	Wide	Wide	Wide
	Planning	Construction planning of smart tourism scenic spots	Very high	Very high	Very high
		Input of security	High	Ordinary	High

$$\mu_{111} = \begin{pmatrix} 0.85 & 1 & 0.94 & 0.59 & 0.35 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix}$$

$$\mu_{112} = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0.83 & 0.67 & 0.5 & 0.33 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix}$$

$$\mu_{113} = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0.83 & 0.67 & 0.5 & 0.33 \\ 1 & 1 & 0.8 & 0.6 & 0.4 \end{pmatrix}$$

$$\mu_{121} = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 0.8 & 0.6 & 0.4 \end{pmatrix}$$

$$\mu_{122} = \begin{pmatrix} 0.75 & 1 & 1 & 0.67 & 0.33 \\ 1 & 0 & 0 & 0 & 0 \\ 0.5 & 0.7 & 1 & 0.86 & 0.57 \\ 0 & 0 & 1 & 0 & 0 \\ 0.85 & 1 & 0.94 & 0.59 & 0.35 \\ 0 & 0 & 1 & 0 & 0 \\ 0.88 & 1 & 0.86 & 0.57 & 0.29 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix}$$

$$\mu_{131} = \begin{pmatrix} 1 & 0.83 & 0.67 & 0.5 & 0.33 \\ 1 & 0.83 & 0.67 & 0.5 & 0.33 \\ 0.6 & 0.75 & 1 & 1 & 0.67 \end{pmatrix}$$

$$\mu_{132} = \begin{pmatrix} 0.8 & 1 & 1 & 0.75 & 0.5 \\ 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$\mu_{141} = \begin{pmatrix} 1 & 1 & 0.8 & 0.5 & 0.3 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix}$$

$$\mu_{142} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix}$$

By using Equation 6 and combining with evaluation index weight in Table 1, the comprehensive membership degree of smart scenic spot A_1 on the second level evaluation index O_{11} for smart grade e_1, e_2, e_3, e_4 and e_5 can be calculated as:

$$u_{1111} = 0.17, u_{1112} = 0.44, u_{1113} = 0.19, u_{1114} = 0.12, u_{1115} = 0.07$$

respectively. It follows that the grade comprehensive membership vector of A_1 with respect to O_{11} is $\hat{u}_{111} = (0.17, 0.44, 0.19, 0.12, 0.07)$. Similarly, the comprehensive membership degree of smart scenic spot A_1 on the second level evaluation indices O_{12}, O_{13} for smart grade e_1, e_2, e_3, e_4 and e_5 can be calculated as:

$$u_{1121} = 0.15, u_{1122} = 0.63, u_{1123} = 0.1, u_{1124} = 0.07, u_{1125} = 0.05;$$
$$u_{1131} = 0.24, u_{1132} = 0.37, u_{1133} = 0.17, u_{1134} = 0.13, u_{1135} = 0.09$$

respectively. It further indicates the grade comprehensive membership vector of A_1 with respect to O_{12} is $\hat{u}_{112} = (0.15, 0.63, 0.1, 0.07, 0.05)$ and with respect to O_{13} is $\hat{u}_{113} = (0.24, 0.37, 0.17, 0.13, 0.09)$. The hierarchical membership matrix of smart scenic spot A_1 with respect to all second-level evaluation indices under the first-level evaluation index O_1 is:

$$\hat{\mu}_{11} = \begin{pmatrix} 0.17 & 0.44 & 0.19 & 0.12 & 0.07 \\ 0.15 & 0.63 & 0.1 & 0.07 & 0.05 \\ 0.24 & 0.37 & 0.17 & 0.13 & 0.09 \end{pmatrix}$$

Similarly, the comprehensive membership degree of smart scenic spot A_1 on the first-level evaluation index O_1 for smart level e_1, e_2, e_3, e_4 and e_5 is given by:

$$u_{111} = 0.18, u_{112} = 0.5, u_{113} = 0.15, u_{114} = 0.1, u_{115} = 0.07$$

The associated grade membership matrix of A_1 with respect to the first-level evaluation indices is:

$$\hat{\mu}_1 = \begin{pmatrix} 0.18 & 0.5 & 0.15 & 0.1 & 0.07 \\ 0.19 & 0.19 & 0.37 & 0.18 & 0.07 \\ 0.25 & 0.21 & 0.21 & 0.22 & 0.11 \\ 0.25 & 0.53 & 0.11 & 0.07 & 0.04 \end{pmatrix}$$

Moreover, the comprehensive membership degree of A_1 over smart level e_1, e_2, e_3, e_4 and e_5 is:

$$u_{11} = 0.21, u_{12} = 0.33, u_{13} = 0.24, u_{14} = 0.15, u_{15} = 0.07$$

which gives the comprehensive membership vector $\hat{u}_1 = (0.21, 0.33, 0.24, 0.15, 0.07)$. Likewise, the other two comprehensive membership vectors concerning A_2, A_3 are $\hat{u}_2 = (0.18, 0.20, 0.26, 0.25, 0.1)$, $\hat{u}_3 = (0.25, 0.31, 0.24, 0.12, 0.08)$.

Obviously, the level eigenvalue of A_1 is:

$$\upsilon_1 = (1,2,3,4,5)\hat{u}_1^T = (1,2,3,4,5)(0.21, 0.33, 0.24, 0.15, 0.07)^T = 2.54$$

given Equation 7. Besides scenic spot A_1, the eigenvalue of A_2 and A_3 is $\upsilon_2 = 2.86, \upsilon_3 = 2.47$. According to Equation 8, the level eigenvalue of A_1, A_2 and A_3 is shown as two-tuple linguistic:

$$\upsilon_1 = (3, -0.46), \upsilon_2 = (3, -0.14), \upsilon_3 = (2, 0.47)$$

Following the previous specifications, the smart level of A_1 and A_2 should be assessed by e_3, and A_3 is assessed by e_2. However, A_1 and A_2 are not at the same smart level and the order for them is given by $A_3 > A_1 > A_2$.

From the comparison of each single index of the three smart scenic spots above, all indices of A_3 are higher than those of A_1 and A_2 in general, while the individual index of A_2 states the worst-case scenario. These results are not only consistent with the comparison of single index, but more rigorous, reliable and intuitive.

As Table 4 shows, the maximum membership principle claims that both A_1 and A_3 scenic spots are ranked at level 2 in terms of smartness, while A_2 is at level 3. While the level eigenvalue evaluation justifies that all three scenic areas ranked at level 2, showing no clear distinction. By utilizing two-tuple linguistic model, however, the rankings for A_1, A_2, and A_3 were 2, 3, and 1, respectively, adhering to a strict ranking criterion. During the smart scenic spot evaluation, both of maximum membership principle and grade eigenvalue evaluation have certain limitations. Although there are slight differences between the results of the smart scenic spots rating, the latter, which is mixed with the two-tuple linguistic method and the two methods above, exhibits a more reasonable, closer fact to the reality. Above all, two-tuple linguistic method, it on the one hand reasonably determines the

Table 4. Smart level assessment results of scenic spots

Scenic Spots	A_1	A_2	A_3
Wisdom level comprehensive membership vector	(0.21, 0.33, 0.24, 0.15, 0.07)	(0.18.0.20, 0.26, 0.25, 0.1)	(0.25, 0.31, 0.24, 0.12, 0.08)
Wisdom level assessed by the of maximum membership principle	2 level	3 level	2 level
Level eigenvalue	2.54	2.86	2.47
Wisdom level assessed by level eigenvalue	2 level	2 level	2level
Two-tuple linguistic	(3, -0.46)	(3, -0.14)	(2, 0.47)
Wisdom level assessed by binary semantics	3 level	3 level	2 level
Order of wisdom degree determined by binary semantics	2	3	1

smart scenic spots level, on the other hand the difference of the smart degree of different scenic spots within the same smart level gets accurately distinguished on the effort of this method.

CONCLUSION

In this study, we developed a weighted index system to evaluate the smart level of scenic spots. By applying this system, we established a fuzzy comprehensive model and introduced a two-tuple linguistic method for evaluation. For the empirical results on the application of evaluation method (see Table 4), we surveyed three 5A-level scenic spots, which are Xiamen's Gulangyu Scenic spot $\left(A_1\right)$, Fuzhou's Sanfang Qixiang $\left(A_2\right)$, and Wuyishan $\left(A_3\right)$, with the exploiting of the maximum membership principle, level eigenvalue evaluation, and two-tuple linguistic model respectively. Our findings revealed that, according to the first method, both A_1 and A_3 scenic spots are ranked at level 2 in terms of smartness, while A_2 is at level 3. The second method claims that all three scenic areas ranked at level 2, showing no clear distinction. By utilizing two-tuple linguistic model, however, the rankings for A_1, A_2, and A_3 were 2, 3, and 1, respectively, adhering to a strict ranking criterion. This comparison echoes the efficiency of two-tuple linguistic model on capturing missing information, which should be deemed as a proven method to enhance the accuracy of smart scenic spots evaluations.

For the derivative theoretical implications, we find that the two-tuple linguistic model not only captures preferences with quantitative representations during decision-making, but also extracts information behind the uncertainty of language using and terminology in evaluations. It mitigates information loss and builds a more accurate and robust result for the sake of smart scenic spots evaluations. Meanwhile, the results demonstrate that the two-tuple linguistic method aligns with the conceptual requirements for evaluating the smart level of scenic spots and its properties is proven to be a practical, efficient, and applicable approach. Our study offers a novel solution to address the evaluation on the smart level of scenic spots and can be adapted for use in other similar cases.

For the management implications, on one hand we offer a viable assessment method for tourism regulatory authorities to determine and evaluate the smart level of scenic spots for a more accurate result. On the other hand, we also provide a foundation of decision-making for scenic spots building, allowing them to discern differences in smart levels to the competitors and further help them to implement several precise business strategies.

COMPETING INTERESTS

The authors of this publication declare that there are no competing interests.

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