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Multilevel grey method for evaluating the exploitation potential of tourism resources based on machine learning

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Abstract: This study proposes a multilevel grey evaluation method integrated with machine learning to assess tourism resource (TR) development potential. Addressing challenges like poor management, resource scarcity, and unsustainable practices, the approach optimises resource allocation through an evaluation system analysing variation and grey weight vectors. Results show steady increases in evaluation weights over time, with average variation weight at 1.87 (total increase: 1.80) and grey weight at 0.50 (increase: 0.21). Compared to traditional systems, the optimised model improved service quality (9.92%), management level (10.25%), and government support (9.07%). This method enhances resource utilisation efficiency and promotes sustainable tourism development by identifying optimal strategies for TR exploitation.

Keywords: tourism resources; development potential; management level; government support; evaluation method; multilevel grey evaluation; machine learning; resource allocation; sustainable development.

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1 Introduction

The development of TR is crucial for the economic growth of many regions, as tourism plays a significant role in driving local economies. However, the potential of tourism resources is often hindered by several challenges, such as poor management practices, resource depletion, and high costs associated with tourism infrastructure and services. In some regions, the rush for short-term profits has led to the blind over-exploitation of TR, resulting in unsustainable practices and the wastage of valuable resources. This is especially evident in areas where there is a lack of comprehensive planning and an overemphasis on immediate economic benefits rather than long-term sustainability. As a result, the imbalance between the growing demand for tourism and the limited capacity of

TR leads to degradation of the environment and diminishes the overall quality of the tourism experience. To address these issues, it is essential to have a scientific and systematic approach to evaluate the development potential of TR. This evaluation helps to identify the strengths, weaknesses, and areas for improvement, ensuring that the development of tourism resources is both sustainable and beneficial to the local communities. The traditional methods of TR evaluation have often been limited in their ability to consider the complex, multi-dimensional factors that affect tourism resource exploitation. Therefore, the use of advanced methodologies, such as the multi-level grey evaluation method, provides a more comprehensive and dynamic framework for assessing the potential of TR development.

TR development is related to the development of local economy. Kim et al. (2019) discussed the priorities of material culture practitioners in developing material culture into a sustainable TR. The results showed that from the perspective of material and cultural practitioners, authenticity was a whole concept, which integrated inherited customs, genetic significance and practitioners' identity. Arshad et al. (2018) believed that tourism developed into a tool to create considerable economic benefits. Pakistan had various tourism destinations in other mountains and historical and archaeological sites. Its tourism potential was huge, which provided tourists with diversified opportunities. Amerta et al. (2018) tried to explain the concept of sustainable development of tourism, and how tourism could achieve sustainable development as an important industry. Baum (2018) focused on neglecting employment or labour in the policy participation and planning of sustainable tourism. He discussed the central role of people and work in the concept of sustainability and sustainable communities, and questioned why this was seriously ignored in the tourism industry. Noordeloos (2018) further studied the overall balance of stakeholder participation, because many researchers emphasised that all stakeholders should participate in tourism planning. Ngoc et al. (2021) analysed the current situation of tourism in terms of sustainable development. He used PESTEL method to investigate tourists in Qinghe Province. The results showed that tourism in Qinghe Province was developing very rapidly, but it was not really sustainable. Hall (2019) used the heterogeneous constructivism method to study the management ecology and sustainable development goals of tourism, which required more reflective understanding of knowledge and management to better understand the impact of knowledge circulation, legalisation and action on sustainable tourism. The above studies all described the relevant content of TR development, but they did not describe the potential evaluation.

The evaluation of TR development potential is related to the development of the environment. Cetin (2018) assessed the tourism potential of Yesilyuva Natural Park through its historical characteristics. This framework aimed to establish the expected tourism sustainability. Dehoorne et al. (2019) evaluated the potential of the local TR for development by studying the TR, and conducted an evaluation study on the development potential of this area. Dodds et al. (2018) conducted a guided review of tourism development literature by using case studies in academic and grey literature to synthesise key elements and challenges for success. Nugroho et al. (2018) planned the development and evaluation of tourism potential from the macro level, which provided a legal management basis for the ecosystem and local level, and expressed that the planning at the ecosystem level designed an environmental and cultural vision. Jaelani (2017) combined the description of halal tourism with the practice of Islamic law in Indonesia. This method found that halal tourism was inseparable from the religious customs of most

Muslims in Indonesia, and also made economic contributions to the local community. The above studies all described the role of TR development potential evaluation, but they are not analysed from multiple perspectives.

This study's primary contribution is the application of the multi-level grey evaluation method to assess the exploitation potential of TR. By addressing challenges like poor management, resource scarcity, and unsustainable development, it introduces a comprehensive and dynamic evaluation system that improves upon traditional methods. The research highlights the importance of monitoring TR development over time through variation and grey evaluation weight vectors, which steadily increase, reflecting the evolving nature of resource management. The study also shows that the new evaluation system significantly enhances service quality, management levels, and government support compared to traditional approaches. Ultimately, this research provides a more systematic, sustainable framework for evaluating and managing TR development, ensuring responsible resource use and promoting long-term tourism sustainability.

2 Construction of TR development potential evaluation system

2.1 Necessity of establishing TR development potential evaluation system

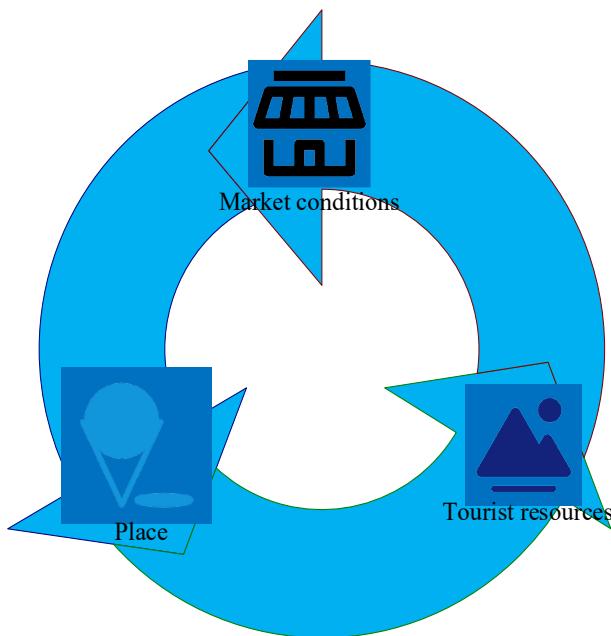
The criteria used in the evaluation system are primarily intended to assess TR during tourism planning. However, the effectiveness of the TR evaluation method has been questioned during the implementation of tourism plans. In TR assessments, the concepts, contents, methods, and results of TR evaluation and TR development evaluation are often confused. The primary objective of TR development is to create tourism products. Therefore, when evaluating TR development, it is essential to consider not only the characteristics of the resources but also factors such as the tourism market, environmental influences, and development conditions (Darsana and Sudjana, 2022). TR evaluation does not consider the market conditions and the evaluation of development sites closely related to TR development, and there are some defects in the actual planning and development of tourism. Therefore, it is necessary to deeply study the evaluation of TR development and establish the evaluation system of TR development potential. The evaluation of TR development potential is to evaluate the prospect of TR basic utilisation, including TR quality, events, development conditions, market efficiency, etc. The purpose of developing TR potential evaluation system is to evaluate the practical application of technologies and methods. When selecting evaluation factors, market conditions, location and TR development should be taken into account, as shown in Figure 1.

2.2 Principles of establishing TR development potential evaluation

In order to objectively, comprehensively and scientifically assess the potential of regional TR development, the review and development of indicator frameworks and assessment methods should follow the following principles, as shown in Figure 2. First, the scientific principle: The selection of TR evaluation indicators, the determination of the importance of indicators, the selection and construction of indicator systems, and the calculation and configuration of data must be based on recognised scientific theories (such as statistical theory, management theory, decision-making theory). Only through accurate and

comprehensive analysis and description of system operation and interrelationship, and full consideration of various factors and coordination, can the indicator system meet the overall needs of sustainable development and TR utilisation. At the same time, duplication of indicators must be avoided. Second, the objective principle: The objective principle that TR evaluation indicators should be evaluated and analysed based on objective facts and reliable data. The so-called objective facts must be obvious, measurable and verifiable. The comprehensive evaluation system for TR development should be suitable and thorough, ensuring a well-rounded assessment of TR. Third, the feasibility principle emphasises that the TR evaluation indicator framework should not be overly complex. The data provided by the indicator system should either be sourced from the existing statistical system or obtained through specific efforts, making it easier to plan resources rationally. Fourth, the guiding principle focuses on using the TR evaluation index system to support sustainable development. The aim is to design and protect the evaluation object in alignment with the shared interests of humanity, nature, and society. Therefore, the indicators and their distribution should align with the region's overall strategic goals for sustainable development.

Figure 1 Factors to consider when evaluating factors (see online version for colours)



2.3 *Characteristics of TR development potential evaluation system*

TR development potential evaluation system has two main characteristics, as shown in Figure 3. First, the improvement of ecological efficiency coefficient of resources. The orderly development of tourism must be based on regional sustainable development. The essence of regional sustainable development is that regional development and natural and cultural environment are common to all mankind and balanced with natural, cultural and humanistic environment (Kongbuamai, 2020). This balanced combination of

different regions is the unique TR of the region. Therefore, TR development costs are closely related to local resources. The quality of tourism environment has become an important issue in the management of many tourist attractions. The environmental quality of tourist destinations is a key concern for tourists and plays a crucial role in the competitive positioning of different destinations. Identifying environmental resource factors within the evaluation indicator framework helps to highlight the value of tourism development. In the current TR assessment system, the focus on environmental and resource protection has led to a reduction in the number of evaluations, with the assessment model failing to account for significant losses of these resources and environments. Additionally, the evaluation of the brand is an important aspect. The TR development potential evaluation index system is designed to support tourism development, forming a product and market evaluation framework. The ultimate aim is to organise and enhance tourism products. This indicator framework enables local authorities and developers to perceive TR development as a high-quality tourism product. Based on this, it is essential to assess the value of well-known tourism products and determine the appropriate development mode and direction, ensuring that tourists can experience the ideal blend of expectations and reality.

Figure 2 Principles for constructing evaluation of tourism resources development potential (see online version for colours)

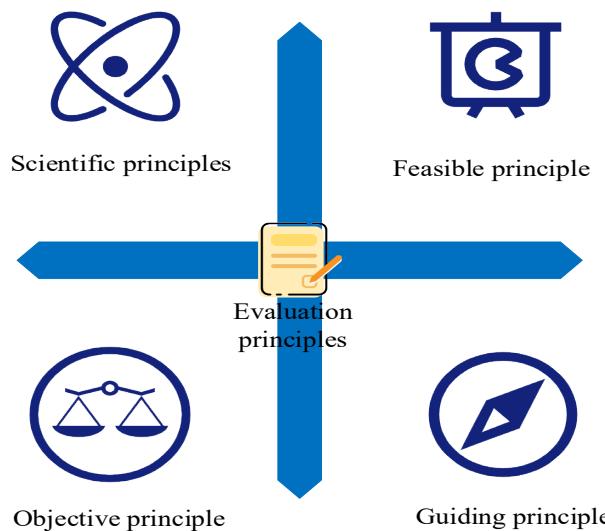
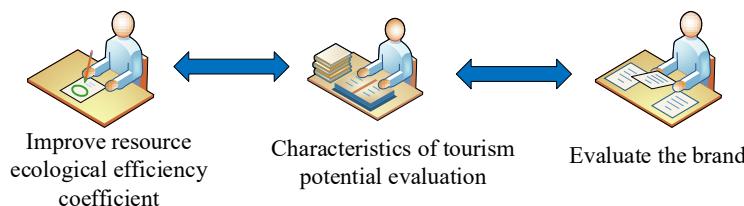


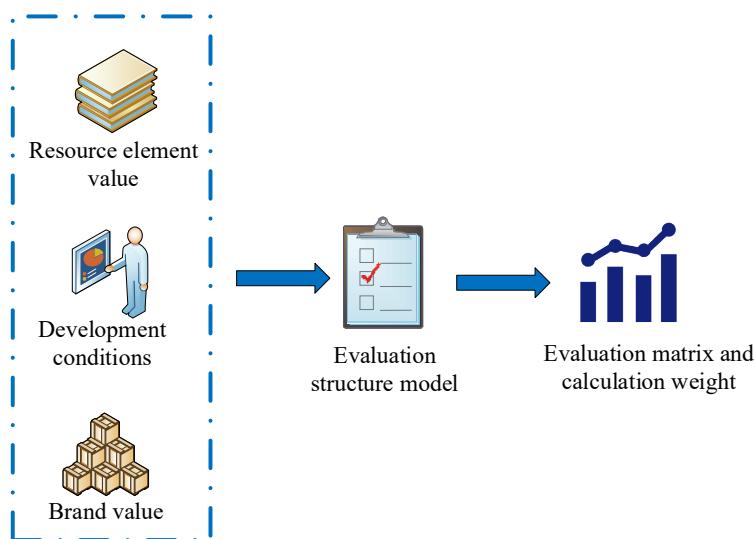
Figure 3 Two characteristics of the tourism resources development potential evaluation system (see online version for colours)



2.4 Establishment of TR development potential evaluation system

Based on the value of resource elements, development conditions and brand value, index evaluation and multi-level grey method are used to establish an evaluation structure model, and the evaluation matrix and weight are calculated, as shown in Figure 4. Common objectives and measurement points should be precisely specified in the indicator framework, mostly for the purpose of assessing the model's output. A methodical endeavour, regional TR development seeks to address issues with the structure, composition, and operational integrity of the tourist system. The significance of tourism-specific elements, such as the TR area, environment, and conditions for tourism development, should be considered when assessing the potential for TR development. Therefore, the evaluation indicators selected for comprehensive evaluation represent the value of resource elements and the development environment. On the other hand, the brand value is selected as the evaluation index to show the potential of TR development in tourism products, especially tourism products. The appraisal project is the key condition for the development of tourism, especially the market conditions, regional conditions, regional conditions, etc. Proximity directly affects the choice of destination and the cost of tourism development investment. The spatial competition and collaboration of tourist attractions are reflected in the geographical relationship. An essential component of regional TR development is infrastructure. The carrying capacity of tourist attractions is determined by the quantity and size of regional tourist attractions, and the quantity of tourist attractions has a direct impact on the quality of TR development. The degree of TR management by all levels of government is reflected in the political climate. The development of TR is somewhat influenced by the socioeconomic circumstances of the surrounding community. The development of TR is generally aided by the high calibre of the population and the high degree of regional social economy.

Figure 4 Establishment process of resource potential evaluation system (see online version for colours)



3 Application of multi-level grey method in tourism potential evaluation system

In order to study the potential evaluation effect of TR development, this paper analyses the specific situation of TR development and the weight index of potential available for development through multi-level grey method, and grades according to the weight effect, so as to determine the actual effect available for development. Firstly, this paper determines the indicator weight A of TR as follows by analysing the coefficient of variation method:

$$A_m = \frac{\sqrt{\sum_{i=1}^k (B_{mi} - \bar{B}_m)^2 / k}}{\bar{B}_m} \sqrt{\sum_{i=1}^l \frac{\sum_{i=1}^k (B_{mi} - \bar{B}_m)^2 / k}{\bar{B}_m}} \quad (1)$$

Among them, A_m is the m index weight; i is the number of scholars evaluated by TR; k is the resource evaluation index; B_m , \bar{B}_m are the overall score and average evaluation score of scholars respectively. The comprehensive weight of TR under the grey algorithm is calculated as follows:

$$A'_i = A_{ai} * A_{bi} / \sum_{i=1}^m A_{ai} * A_{bi} \quad (2)$$

Among them, A'_i is the comprehensive weight of TR. A_{ai} , A_{bi} are the weights obtained by coefficient of variation method and grey algorithm respectively. Next, the evaluation index matrix of TR development potential resources is as follows:

$$C^{(v)} = \begin{bmatrix} c_{111}^{(v)} & c_{112}^{(v)} & \cdots & c_{11n}^{(v)} \\ c_{121}^{(v)} & c_{122}^{(v)} & \cdots & c_{12n}^{(v)} \\ \vdots & \cdots & \cdots & \vdots \\ c_{1m1}^{(v)} & c_{1m2}^{(v)} & \cdots & c_{1mn}^{(v)} \end{bmatrix} D_{11n} \quad (3)$$

Among them, $c_{1mn}^{(v)}$ is the scholar's score of index D_{11n} of the v th region, and then the evaluation coefficients of TR potential score are calculated as follows:

$$P_{1mn}^{(v)} = \sum_{i=1}^n g(c_{1mn}^{(v)}) \quad (4)$$

$$P_{1m}^{(v)} = \sum_{n=1}^N P_{1mn}^{(v)} \quad (5)$$

Among them, $P_{1mn}^{(v)}$ is the comprehensive index of coefficient of variation evaluation; $P_{1m}^{(v)}$ is the comprehensive index of grey evaluation coefficient. The variation evaluation weight vector and grey evaluation weight vector of TR development potential evaluation are as follows:

$$h_{1mn}^{(v)} = \frac{P_{1mn}^{(v)}}{P_{1m}^{(v)}} \quad (6)$$

$$h_{1m}^{(v)} = (h_{1m1}^{(v)}, h_{1m2}^{(v)}, h_{1m3}^{(v)}) \quad (7)$$

The final comprehensive evaluation of tourism development potential is as follows:

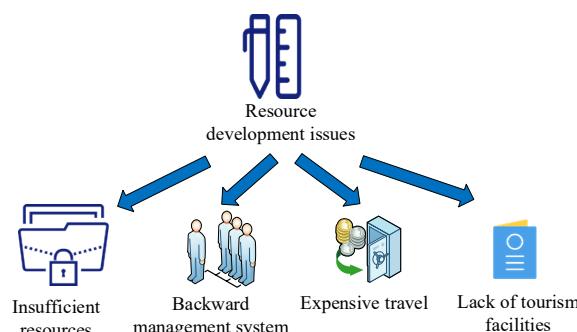
$$T^{(v)} = \left(\frac{h_{1mn}^{(v)}}{h_{1m}^{(v)}} \right) \bullet C^{(v)} \quad (8)$$

4 Problems in TR development process and optimisation strategy

4.1 Problems in TR development

Through the establishment of the TR evaluation system, it can learn that there are several problems in the current TR development, as shown in Figure 5. First, resources are insufficient. The lack of protection and management of resources also led to violations. For example, the construction of large quarries in the park and the collection of grass by residents and tourists in the reserve greatly reduce the value of tourism in the tourist area. Second, the management system is backward. The main governance issues are property rights and administrative power. The uneven distribution of interests between tourism development units and local governments, the independence of various departments in the tourist area and the mutual transfer of property make it difficult to manage the tourist area. Poor management of tourist attractions severely limits the sustainable development of these areas. In addition, backward management, lack of tourism experts, lack of innovation ability, blind pursuit of design and product development are the main problems that lead to the destruction and waste of local TRs. Third, travel costs are expensive. Tourism developers blindly increase tickets to tourist areas to support the development of tourism, and they lack contact and cooperation with other tourist attractions, hotels, travel agencies and other tourism enterprises and institutions in the region. As a result, there is not a true tourism chain. Simultaneously, the unequal allocation of interests between local governments and tourism developers has significantly lowered visitor satisfaction and sentiments and harmed the area's positive reputation, which also interferes with regular operations and is not supportive of the scenic area's sustainable growth. Fourth, the absence of tourist amenities is mostly brought on by a lack of landmarks, few restrooms, subpar conditions, erratic parking, and inexpensive transportation (Adeola and Evans, 2020; Wang et al., 2024). In addition, TR is the first tourist attraction in the tourist area, and the service quality is the spiritual window of the tourist area and the key to the development of the tourist area.

Figure 5 Several problems in the current tourism resources development (see online version for colours)



4.2 Optimisation strategy in TR development process

In order to improve the potential of TR development, it is necessary to develop TR rationally, so as to achieve sustainable development of TR. Aiming at the problems existing in the development, some optimisation strategies are proposed. The first is TR integration. TR integration is a process of continuous development and competition for TR. It would be much better to jointly develop resources in different regions than in other regions. In addition, the two sides can strengthen cooperation in tourism, including mutual recognition of opportunities, which would create favourable conditions for the comprehensive development of TR. The second is the scientific management of resources. If governments at all levels want to earnestly implement policies and measures to support the development of tourism and speed up the solution of problems hindering the development of tourism, they must pay attention to ideas and take practical actions. Through in-depth research and scientific evaluation of TR, a sound regional TR plan is formulated to determine and manage the overall direction of tourism development (Wu and Liu, 2024; Qian and Wang, 2024). The third is to change the TR management mode. It is necessary to set reasonable ticket prices for tourist areas and establish free opening days for tourist areas; discount tickets for accommodation in the catering area and free small transportation between scenic spots are provided; citizens are encouraged to stay at home and provide tourists with small tourist routes. At the same time, they can share the achievements of tourism development, and strengthen public participation, so as to combine tourism with poverty alleviation. The fourth is to improve the infrastructure of the tourist area, including marking, cleaning, parking, transportation, accommodation, catering, etc. While improving the tourist experience, the construction of the facilities of the scenic spots and historic sites project should be encouraged. Fifth, resource protection must be strengthened. TR development must be based on scientific protection. In combination with the actual situation of the tourist area, scientific and effective TR protection regulations have been formulated. In addition, any illegal act that damages or destroys TR shall be severely punished according to relevant regulations.

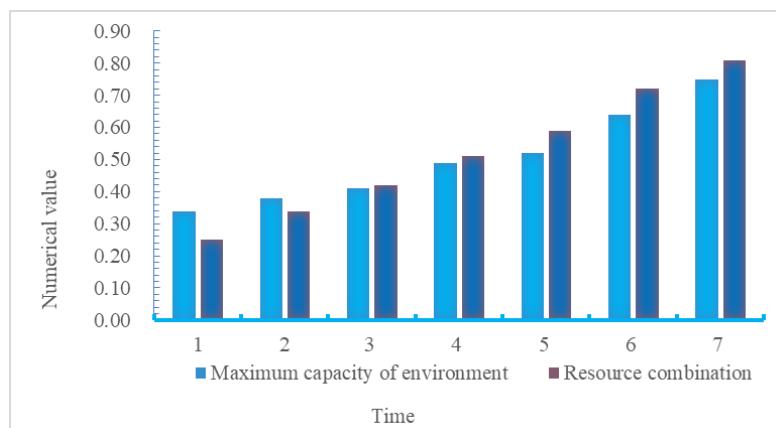
5 Experimental evaluation of TR development potential evaluation system

This work examines the variation coefficient evaluation weight vector and grey evaluation weight vector in the TR development process using the multi-level grey approach in order to investigate the particular application effect of the TR development potential evaluation system. The final evaluation function of TR development potential is derived from the specific modifications of the two, and a set of development strategies that support the sustainable growth of local tourism are developed based on the evaluation function in order to encourage resource development and utilisation as well as economic advancement. This study first examines how satisfied staff members in three regions' tourism development departments are with the mechanism for evaluating development potential. The tourism departments of each region survey 100 people, as shown in Table 1.

Table 1 Satisfaction of tourism development departments in the three regions with the development potential evaluation system

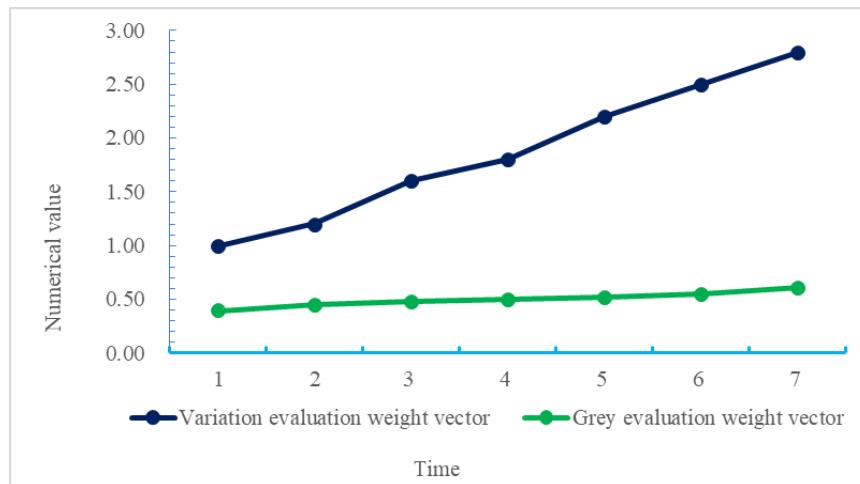
	<i>Satisfied</i>	<i>Commonly</i>	<i>Dissatisfied</i>
Zone 1	88	5	7
Zone 2	85	9	6
Zone 3	82	8	10
Total	255	22	23

According to the data described in Table 1, the staff of tourism development departments in the three regions are generally satisfied with the development potential evaluation system. Among satisfied employees, the number of satisfied employees in Region 3 is the least, accounting for 32.2% of the total; Region 1 has the largest number of satisfied people, accounting for 34.5% of the total. Among ordinary employees, the number of employees in Region 1 is the smallest, accounting for 22.7% of the total number of ordinary employees; Region 2 has the largest average population, accounting for 40.9% of the total. Among the unsatisfied employees, Region 3 has the largest number of unsatisfied employees, accounting for 43.5% of the total; Region 2 has the least number of dissatisfied people, accounting for 26.1% of the total number of dissatisfied people. On the whole, the satisfied employees in the three regions account for 85% of the total survey population. The average employees account for 7.3% of the total survey population, and the dissatisfied employees account for 7.7% of the total survey population. Satisfied employees in the three regions think that the TR development potential evaluation system can help them to reasonably allocate and develop according to the local resources. By formulating a reasonable development plan to maximise the utilisation of resources, it can not only realise the comprehensive development and utilisation of resources, but also promote the healthy development of economy and environment. Unsatisfied employees believe that the resource development evaluation system can only limit their development and utilisation of resources. The changes of the maximum capacity of the environment and the combination of resources after TR development optimisation are analysed, as shown in Figure 6.

Figure 6 Change of maximum environmental capacity and resource combination after optimisation of tourism resource development (see online version for colours)

It can be seen from Figure 6 that the maximum capacity of the environment and the combination of resources after TR development optimisation are gradually increasing over time. Among them, the average value of maximum environmental capacity is about 0.50, and the average value of resource combination is about 0.52. On the whole, the initial maximum capacity of the environment is 0.34, and it increases to 0.75 on the seventh day. This increases by 0.41 throughout the process; the initial value of resource combination is 0.25, and it increases to 0.81 on the seventh day. This increases by 0.56 throughout the process. On the first day and the second day, the resource combination is higher than the maximum capacity of the environment. On the third day, the resource combination is higher than the maximum capacity of the environment. The increase of environmental capacity and resource combination after resource development optimisation shows that the TR potential evaluation system can limit the blind development and waste of resources, which can not only ensure the sustainability of the environment, but also realise the long-term rational utilisation of resources. The multi-level grey method is used to analyse the variation evaluation weight vector and grey evaluation weight vector of TR development potential evaluation. The specific changes of the two are shown in Figure 7.

Figure 7 Variation evaluation weight vector and grey evaluation weight vector of tourism resources development potential evaluation (see online version for colours)

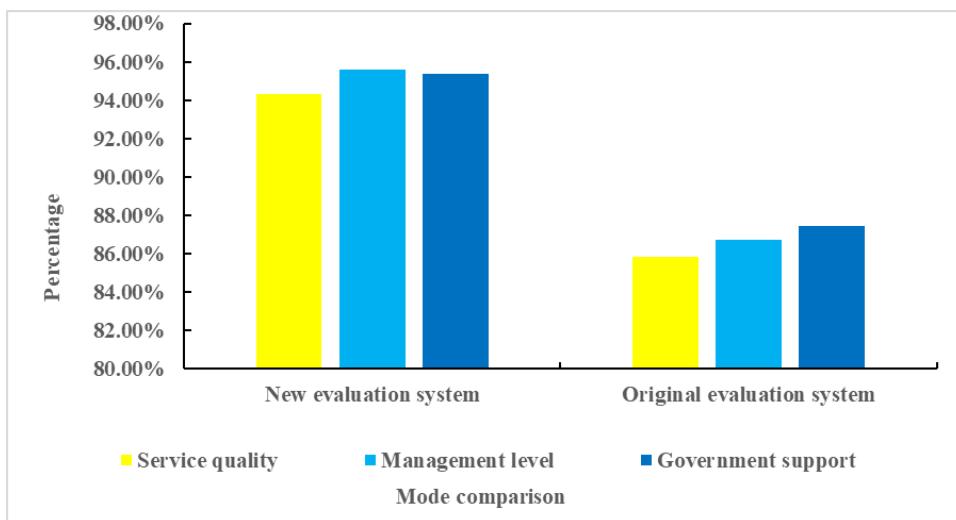


It can be seen from Figure 7 that the variation evaluation weight vector and grey evaluation weight vector of TR development potential evaluation are gradually rising over time. Among them, the mean value of variation evaluation weight vector of TR development potential evaluation is about 1.87, and the mean value of grey evaluation weight vector is about 0.50. On the whole, the initial value of the variation evaluation weight vector of TR development potential evaluation is 1.00, rising to 2.80 on the seventh day. It rose by 1.80 in the whole process; the initial value of grey evaluation weight vector is 0.40, which increases to 0.61 on the seventh day. This increases by 0.21 throughout the process. The rise of variation evaluation weight vector and grey evaluation weight vector shows that TR development potential evaluation system can scientifically plan the integration of resources and coordination between regions.

By improving the laws and regulations of TR, the accuracy of TR potential evaluation is promoted. Finally, the service quality, management level and government support of scenic spots under the TR development potential evaluation system are analysed and compared with the original TR development, as shown in Figure 8.

According to Figure 8, the service quality, management level and government support of scenic spots under the TR development potential evaluation system are better than the original TR development evaluation system. Among them, the service quality of scenic spots under the TR development potential evaluation system is 9.92% higher than the original TR development evaluation system; the management level is 10.25% higher than the original TR development evaluation system; the government support increases by 9.07% compared with the original TR development evaluation system. Under the TR development potential evaluation system, both the service level of the scenic spot and the government's development support would be better than before, and the development of resources would also tend to rationalise. There would be no abuse or waste of resources, and all resources would be used rationally and sustainable.

Figure 8 Changes in service quality, management level and government support of scenic spots under the evaluation system of tourism resources development potential (see online version for colours)



6 Conclusions

This study successfully applied the multi-level grey evaluation method to assess the exploitation potential of TR, providing a comprehensive framework that integrates environmental, management, and market factors. The results demonstrated significant improvements in key areas such as service quality, management level, and government support compared to traditional evaluation systems. By emphasising sustainability and the rational use of resources, the research contributes to the optimisation of TR development and highlights the importance of continuous monitoring and adjustment. However, the study has certain limitations, such as the reliance on available data, which may not fully capture all regional or seasonal variations in tourism resources.

Additionally, while the multi-level grey evaluation method offers a robust framework, further refinement is needed to account for more specific contextual factors, such as socio-economic influences and cultural aspects, which can also impact the effectiveness of TR development. Future research could focus on expanding the evaluation system to include these factors, as well as incorporating real-time data collection methods, to further enhance the accuracy and applicability of the evaluation framework.

Conflicts of interest

The authors declare no conflict of interest.

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