Multi-Criteria Decision-Making Evaluation

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China is a major maritime country with numerous islands, which are rich in natural resources. Island resources exhibit excellent development potential; in this regard, the market demand for uninhabited island development has been strong. The scientific and reasonable utilization of the resources of uninhabited islands can create huge economic value for the region and the country, inject vitality into the national economy, and enhance the stability of the overall sustainable development of the national economy. However, previous research on islands focused on a limited area of economy or ecology, and few studies provide a comprehensive evaluation of uninhabited island development. Such development requires enormous investment and has a profound impact. Therefore, a comprehensive and scientific evaluation system is necessary for uninhabited island development planning. This entry accordingly develops an island planning and evaluation indicator system based on multi-criteria decision-making (MCDM), and entropy analysis method, and the approach of Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS).

Keywords: island development ; island development plan ; island investment

1. Introduction

Research Background

With rapid economic development, China has entered a critical phase in building a modern society. Thus, given that modernization requires the coordination of various land and sea resources, development solely with inland resources cannot meet the needs of the sustainable development of the national economy. Therefore, the unique economic value of coastal islands has become prominent. According to the Ministry of Natural Resources of the People's Republic of China (MNRC) report, there are over 11,000 islands in China. Although the total area of the islands accounts for only 0.8% of China's total land area, as unique geographical units, these islands can provide rich natural resources to contribute to regional and national economic development [1]. For example, the development of island scenic areas can offer significant economic value to residents, the government, tourism, transportation, and other related supporting industries [1]. China's marine GDP increased from 7.0507 trillion Yuan Renminbi (RMB) in 2016 to 8.9415 trillion Yuan RMB in 2019, with an average annual growth rate of 6.6%, accounting for 9% of the national GDP. However, China's marine GDP was 8.001 trillion Yuan RMB in 2020, reduced by 5.3% compared to 2019, due to the pandemic. Thus, the island economy has demonstrated its vital importance in the marine economy and China's sustainable development [1].

The marine economy in Chain has played an extremely critical role in the development of the national economy and ongoing modernization. Given the consumption structure upgrade, income-per-capita increase, and the stable and robust demand for tourism, coastal tourism has become an important factor in island economic development. In addition, the islands are an essential supporting element for marine production activities, helping the marine transportation, fishery, and shipbuilding industries. As an important part of the marine economy, the island industry has its special status in terms of economy, nature, ecology, and politics. Island resources have a unique geographical location and ecological environment, which has exhibited excellent development potential. Therefore, the market demand for uninhabited island development has been strong. With the development of the island economy and strategy, there are strict restrictions and requirements for island development planning and subsequent development.

Islands are generally classified into inhabited islands and uninhabited islands, according to the status of the resident population. According to the characteristics of the resident population, the development and investment planning of inhabited islands can be classified into the following five categories: (1) islands for agriculture, forestry, and animal husbandry; (2) islands for tourism and recreation; (3) islands for urban and rural constructions; (4) islands for fishery; and (5) islands for public services. On the other hand, the development and investment planning of uninhabited islands can be classified into the following five categories: (1) islands for storage, (2) islands for industrial applications, (3) islands for renewable energy, (4) islands for transportation, and (5) islands for reservation.

Due to limitations of local cultural inheritance and historical reasons, the development of inhabited islands is usually a modification of the current situation. In contrast, uninhabited islands afford more planning and investment choices because of their undeveloped states. The development plan can assist the uninhabited island itself or the regional economy by developing agricultural, industrial, and service industries to promote optimization in land and sea coordination.

Many island development programs have received great attention because of the strategic development of the island economy and political needs. An effective island development program can improve island ecology and boost economic growth for three reasons:

(1) The island has a fragile ecological environment due to its simple biological chain. A scientific island development strategy can effectively improve the island's ecosystem and its surrounding waters to compensate for ecological defects.

(2) The current scale of the island economy in China is small, with a simple and single structure, with marine fishery being the primary contributor to the GDP of the regions with islands. The island economy can be much more diversified. For example, island tourism can effectively promote economic development and local employment because of the unique landscape and culture.

(3) The islands are weak in their economic foundation. The lagging infrastructure construction of water, electricity, and transportation and the regional energy vulnerability will lead to an increasingly large gap between islands and mature industrial economies in coastal and inland areas, and it is difficult to form a pattern of coordinated development of regional economies [2]. Due to the conditions of the island, reasonable planning can help reduce the disadvantages of the island and even transform them into development advantages, and realize the coordinated economic and social development of the island and its surrounding regions. A good development plan can transform the disadvantages of the island into advantages and achieve coordinated development with its surrounding areas. On the contrary, the wrong government decision-making scheme can not only fail to promote the sustainable development of island development but even cause some enterprises to damage the environment of islands and the surrounding sea areas at the cost of sustainable development [3], thus negatively impacting the sustainable development of China's economy. Therefore, at the end of 2018, the Chinese National Development and Reform Commission and the Ministry of Natural Resources decided to develop 14 marine island economic development demonstration zones. Thus, these island development programs are expected to bring new opportunities for economic development in China.

2. MCDM's Evaluation of Policies and Programs

Multi-criteria decision-making (MCDM) has been applied by many decision-makers and researchers to solve complex problems since it was put forward. MCDM can be used for the government to formulate policies and plans and for the selection of large investment projects. In addition, it is widely used in general organizations, enterprises, etc., [4]. In short, MCDM has been successfully applied to a wide variety of problems. MCDM refers to selecting from a candidate pool containing finite, infinite, conflicting, and incompatible alternatives. MCDM has been applied in various fields since its introduction as a standard decision-making method in the 1960s. Many decision-makers and researchers have used it to solve complex problems involving many factors. For example, Seker and Kahraman [5] used an MCDM model to select a solar photovoltaic panel manufacturer for a solar power plant in Anatolia in southeast Turkey. Abdel-Basset et al. [6] used an MCDM model to evaluate the sustainability of hydrogen production schemes. Furthermore, Loganathan et al. [7] used an MCDM method to select Li-Ion batteries for electric vehicles. Hsu et al. [8] used a hybrid MCDM method to help ship carriers choose docking ports for cost savings. Rubio-Aliaga et al. [9] used MCDM to evaluate and determine groundwater extraction solutions. MCDM includes many methods, such as analytic hierarchy process (AHP), Elimination and Choice Expressing Reality (ELECTRE), preference-ranking organization method for enrichment evaluations (PROMETHEE II), complex proportional assessment (COPRAS), TOPSIS, and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Each method has its advantages and disadvantages. AHP is one of the methods to solve MCDM problems [4]. Hatami-Marbin et al. [10] pointed out that the framework of AHP is controversial because the program is lack of transparency and the calculation is complicated. Therefore, among many MCDM methods, AHP does not have a significant advantage. ELECTRE is a well-known method in MCDM. However, ELECTRE only provides the ranking of each alternative and lacks objective data to help further understand the differences between alternatives [11]. PROMETHEE method aims to reduce the limitations of ELECTRE [12]. PROMETHEE II has a clear calculation process and lowers computational complexity than ELECTRE, but PROMETHEE has shortcomings in problem design and weight determination [10]. The COPRAS method ranks and evaluates the importance and usefulness of alternatives [13]. The main advantage of COPRAS is its ease of use and friendliness; however, this approach has shortcomings in dealing with qualitative indicators and characteristics [14]. TOPSIS and VIKOR are widely used in MCDM. VIKOR is similar to TOPSIS. TOPSIS uses vector normalization, while VIKOR uses linear normalization, so TOPSIS has a higher resolution [15]. In addition, the use of VIKOR is more complicated, while TOPSIS requires fewer mathematical operations to make effective decisions [12]. It can also be used simply when the number of alternatives and indicators is large [11].

Various studies in the context of MCDM emphasize the use of simple and understandable technologies to deal with MCDM problems, and the calculation should be simple and economical [15]. It can be seen from the above that the TOPSIS method has practicability in dealing with MCDM problems compared with the methods proposed above. TOPSIS has low operational complexity and very transparent logic, which is applicable to both qualitative and quantitative information.

In 1981, Yoon and Hwang proposed TOPSIS, which is an analytical method for solving complex decision-making problems. TOPSIS can clearly compare and analyze the priority of the factors involved. The basic idea of TOPSIS is to define positive ideal solution (PIS) and negative ideal solution (NIS). The negative ideal solution is the opposite; that is, the evaluation benefit is the least, and the cost is the largest. The optimal solution is the one closest to the positive ideal solution and furthest from the negative ideal solution. Through PIS and NIS assessments, TOPSIS can assist decision-makers to fully consider the needs of different stakeholders to select the best solution. This method cannot only calculate the value of all alternatives by using relevant tools but can also rank all alternatives in order of merit to help decision-makers make choices.

In the evaluation method of MCDM, the weight value of indicators will directly affect the evaluation results, and different weight values of indicators will lead to completely different results. Indicators can be divilded into subjective and objective categories [16]. The weight of subjective indicators is based on the subjective judgment of decision-makers and the relative importance of each indicator is given by subjective cognition. Since it is subjective recognition, the weight is relatively stable and not easily affected by the evaluation matrix, the problem of biased evaluation results may occur. The objective weight is distributed according to the objective conditions, so as to avoid the distortion caused by the subjective bias of decision-makers. Indicators can generally be divided into subjective and objective categories [16]. The weight of subjective indicators is based on the subjective judgment of decision-makers, and the relative importance of each indicator is given by subjective cognition. Since it is subjective recognition, the weight is relatively stable and not easily affected by the evaluation matrix, the problem of biased evaluation results may occur. The objective weight is distributed according to the objective conditions so as to avoid the distortion caused by the subjective bias of decision-makers. Entropy is an objective method of weighting indicators by applying the concept of entropy value to calculate the relative weight of each indicator. In this method, the entropy value is calculated by measuring the weight of each index to explain the degree of influence of this index on the decision-making problem in the whole process. Then the relative weight of each index is calculated by comparing the entropy value. Therefore, entropy is applied to the index to calculate its weight. The larger the entropy value of an index is, the larger the weight of this index will be; thus, the importance of different indexes can be distinguished [17].

Previous studies indicated that the entropy and TOPSIS methods are important in effectively and quickly solving problems in evaluating investments and development strategy management [16].

2.1. The Application of Entropy and TOPSIS to Project Evaluation

Several previous studies have combined Entropy–TOPSIS to build models to solve complex problems of system evaluation or solution selection. In this regard, several publications focus on system evaluation. For example, Wu et al. [18] propose the construction principles and processes of the safety index system for the operation of urban rail transit stations based on the improved Entropy–TOPSIS and construct the safety evaluation index system for the operation of urban rail transit stations. Li et al. [19] use the Entropy–TOPSIS to construct a risk management assessment system for historical and cultural sites in 31 provinces of China to assess provincial conservation priorities. Sun et al. [20] adopted the Entropy–TOPSIS and the K-means to score and evaluate building energy performance. Li [21] used Entropy–TOPSIS to build a model to evaluate the carrying capacity of the ecological environment around Longquan Mountain in Chengdu City. Xu et al. [22] constructed a model to evaluate the sustainability of megacities. Du and Gao [23] used AHP and Entropy–TOPSIS to build a model to evaluate the ecological security of marine aquaculture. Moreover, Zhao et al. [24] constructed a national power development evaluation model. Salehi et al. [25] used Entropy–TOPSIS to evaluate crisis management systems in the petrochemical industry. Finally, Zheng et al. [26] evaluated the physiological safety of sanitation workers under high temperatures.

Several studies focus on solution selection. For example, Jatin et al. [27] use the Entropy weight method (EWM) to calculate the weight of aim factors and then uses the Entropy–TOPSIS to prioritize the selection of household water purifiers. Chodha et al. [28] select industrial robots for arc welding operations using the Entropy–TOPSIS method. Khodaei et al. [29] use TOPSIS–Shannon Entropy to construct an evaluation system for strawberry coatings to evaluate the priority of different food coatings. Albahri et al. [30] developed a new framework to solve a prioritization problem for patients infected with COVID-19. Furthermore, Alao et al. [31] used Entropy–TOPSIS to select the best technical solution for waste-to-energy conversion. The above research shows that the decision-making models based on Entropy–TOPSIS in MCDM have been successfully applied in various fields.

2.2. Advantages and Disadvantages of Using Entropy and TOPSIS

The advantages of Entropy and TOPSIS are summarized as follows: (1) In terms of advantages, Entropy is an objective tool for attribute evaluation, and its advantages are reflected in the calculation of Entropy weight from a given raw datum without personal subjective factors. The index weight has strong objectivity to ensure the scientific nature of the evaluation conclusion; its results are consistent with the intuitive decision, easy to be understood, and accepted by decision-makers; and it has advantages over other methods to determine index weight [32]. The TOPSIS method is an effective method to solve the problem of multi-attribute decision-making with finite solutions. The principle of this method is to rank the solutions by calculating the difference between each solution and the ideal solution along with the negative ideal solution, so as to determine the optimal one. Its advantages are its simple calculation, that it is easy to understand, and it has a better ability to integrate other methods. When combining the idea of Entropy and TOPSIS, Entropy determines the weight of the index to be evaluated, and TOPSIS approximates the ideal solution to determine the final order of the objects to be evaluated. Therefore, the combination of Entropy and TOPSIS provides a clear evaluation principle, strong operability, and a strong range of adaptation [25].

Although Entropy combined with TOPSIS has been used successfully in a large number of cases, it also has its disadvantages. Compared with its advantages, the disadvantages are defined as follows: (2) On the disadvantaged part, Entropy and TOPSIS both take advantage of the diversity of data. Consequently, when the diversity of attribute data of an indicator is too high, the combination of Entropy and TOPSIS may exaggerate the role of attributes with a high diversity of attribute data in decision-making [33]. In addition, one of the important factors of MCDM in the application is indeed the selection of indicators. If indicators cannot be effectively evaluated for the program selected, the evaluation results of the whole evaluation program will be mistaken. The Delphi method can make up for this deficiency. As a subjective and qualitative method, the Delphi method can be widely used in the establishment of various evaluation indicator systems and the determination of specific indicators, and it is a favorable auxiliary tool for the implementation of the MCDM method [17][34]. Thus, the Delphi method was used in this study to improve the lack of Entropy and TOPSIS methods applied to solutions in determining the selection of indicators.

Given the above analysis of advantages and disadvantages, this study constructed an evaluation system by combining Entropy with TOPSIS to quantify decision indicators with objective and consistent weights, thereby adding persuasiveness to plans with higher priority calculations [17]. This study synthesized previous studies on island economy and ecology, took into account economic and ecological factors in island development, and constructed an island evaluation and decision model combining Entropy and TOPSIS to improve the island development evaluation system and promote the sustainable development process. First, the model used the Delphi method to comprehensively determine the indicator factors involved in island development evaluation. Then it applied Entropy to obtain the relative weight of each indicator in the island development evaluation system. Finally, the choice of island development strategy was systematically solved by using the TOPSIS calculation and the rank of the alternatives.

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