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Using the Entropy and TOPSIS Models to Evaluate Sustainable Development of Islands: A Case in China

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Abstract: 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 paper 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). A validation analysis was conducted to prove the effectiveness of the evaluation system. The evaluation system comprehensively considers both economic and ecological factors, which makes up for the one-sidedness of the previous evaluation focusing on economy or ecology, and effectively ensures the sustainable development of island development. In this regard, the evaluation system can provide important guidance for the government's island planning management and the investment decision-making of enterprises. This system can also provide new ideas for the sustainable development of islands.

Keywords: island development; island development plan; island investment; multi-criteria decision-making (MCDM); entropy; Technique for Order Preference by Similarity (TOPSIS)

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1. Introduction

1.1. 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.

1.2. Motivation and Purpose

For its unique geographical location and ecological environment, the development investment for an island is quite substantial. Therefore, a scientific and sustainable construction plan is necessary. On the contrary, a wrong plan can destroy the island and its surrounding environment, thus negatively affecting the marine economy. Therefore, it is urgent and critical to develop a scientific and rational evaluation system for island development and planning.

Many researchers used different evaluation methods to propose distinct development strategies for islands, mainly including the following two categories:

(1) The research focuses on island economic development [4–8]: The above studies focus on island economic development and highlight that rapid development of islands depends on tourism and fishery programs, and investment and infrastructure are important measures to promote regional economic development. Although some studies suggest the importance of environmental protection, most do not provide further evaluations and solutions.

(2) The research focuses on island ecological and environmental protection [9–12]: The above studies focus on island ecological protection and highlight the importance of resources and ecological protection and a sustainable long-term development strategy. Island development affects the ecological quality of the island. Overdrawing natural resources for economic development violates the principle of sustainable development. Therefore, the island development plan should be optimized to protect the ecological system.

The above two types of studies indicate that previous studies on island development mainly focus on a single field, and there are few comprehensive studies on island development that thoroughly consider economic and ecological factors. The development of islands not only involves local economic development and ecological protection but also requires huge investment, which has a broad and far-reaching impact. Therefore, economic development and ecological protection, as well as other factors, must be considered comprehensively to ensure the healthy development of islands. Chi et al. [13] pointed out that economic development and ecological protection are mutually affected but not contradictory. High-quality human activities can improve the health of the island ecosystem. Therefore, there is a win-win situation for both economic development and ecological improvement in island development. Considering both economic development and ecological protection is an effective way to maximize the benefits of island development. Therefore, it is an urgent problem to construct a comprehensive scientific and sustainable island development evaluation system.

Since there were few previous studies to comprehensively address island development, this paper proposes an evaluation system on island planning and resource allocation to consider both economic and ecological indicators to achieve coordinated development of the economic and ecological environment for the island region.

To sum up, the introduction of this study introduces the research background, motivation, and purpose, and the main research structure and core are specifically described in the following four parts: Section 2 offers a review of the literature, Section 3 discusses the methods and give an evaluation, Section 4 presents the results and offers discussions, and Section 5 contains conclusions and suggestions. Finally, the conclusion is specifically summarized.

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., [14]. 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 [15] 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. [16] used an MCDM model to evaluate the sustainability of hydrogen production schemes. Furthermore, Loganathan et al. [17] used an MCDM method to select Li-Ion batteries for electric vehicles. Hsu et al. [18] used a hybrid MCDM method to help ship carriers choose docking ports for cost savings. Rubio-Aliaga et al. [19] 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 [14]. Hatami-Marbin et al. [20] 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 [21]. PROMETHEE method aims to reduce the limitations of ELECTRE [22]. PROMETHEE II has a clear calculation process and lowers computational complexity than ELECTRE, but PROMETHEE has shortcomings in problem design and weight determination [20]. The COPRAS method ranks and evaluates the importance and usefulness of alternatives [23]. The main advantage of COPRAS is its ease of use and friendliness; however, this approach has shortcomings in dealing with qualitative indicators and characteristics [24]. 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 [25]. In addition, the use of VIKOR is more complicated, while TOPSIS requires fewer mathematical operations to make effective decisions [22]. It can also be used simply when the number of alternatives and indicators is large [21].

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 [25]. 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 [26]. 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 [26]. 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 [27].

Previous studies indicated that the entropy and TOPSIS methods are important in effectively and quickly solving problems in evaluating investments and development strategy management [26].

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. [28] 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. [29] 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. [30] adopted the Entropy–TOPSIS and the K-means to score and evaluate building energy performance. Li [31] 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. [32] constructed a model to evaluate the sustainability of megacities. Du and Gao [33] used AHP and Entropy–TOPSIS to build a model to evaluate the ecological security of marine aquaculture. Moreover, Zhao et al. [34] constructed a national power development evaluation model. Salehi et al. [35] used Entropy–TOPSIS to evaluate crisis management systems in the petrochemical industry. Finally, Zheng et al. [36] evaluated the physiological safety of sanitation workers under high temperatures.

Several studies focus on solution selection. For example, Jatin et al. [37] 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. [38] select industrial robots for arc welding operations using the Entropy–TOPSIS method. Khodaei et al. [39] use TOPSIS–Shannon Entropy to construct an evaluation system for strawberry coatings to evaluate the priority of different food coatings. Albahri et al. [40] developed a new framework to solve a prioritization problem for patients infected with COVID-19. Furthermore, Alao et al. [41] 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 [42]. 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 [35].

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 [43]. 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 [27,44]. 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 [27]. 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.

3. Method and Evaluation

This study adopted Dachan Island in Nanshan District of Shenzhen city as the research object and constructed an island development evaluation system with both economic and ecological aspects through multi-criteria decision making. Because Dachan Island has been included in the planning scope of new coastal city centers, the island development plan is under examination to determine the best development option. In the plan of Qianhai New

Urban Center Planning Optimization, part of the Baozhong area, Dachan Bay, and Dachan Island are included in the construction scope of the new Qianhai Central Area. In the overall layout planning of "one bay, two mountains, four districts, and four islands", Dachan Island is positioned as a Shenzhen–Hong Kong innovative cooperation island—a free trade port. In addition, according to the actual situation, the previous positioning plan, and the existing facilities in Shenzhen island, a targeted program was put forward with four kinds of development plans. They are (a) industrial island, (b) innovation cooperation Shenzhen and Hong Kong island (free trade port), (c) transportation island, and (d) energy industrial island. This study constructed an island development evaluation system from both economic and ecological aspects and tested whether the results of the evaluation system proposed in this study were consistent with the actual development direction of Dachan Island based on the actual situation of the previous development case, so as to verify the practical application value of the evaluation system proposed in this study. The Dachan Island case is a typical example. The research on this island is beneficial because many analytical procedures and conclusions can be generalized for other islands. This paper builds an evaluation indicator system for island planning by using a collection of works from the literature, the Delphi method, and the MCDM approach. This paper's research is divided into three stages. In the first stage, the literature was collected on evaluation indicators for island development, and the Delphi method was used to determine evaluation criteria to establish an evaluation system. In the second stage, an entropy method was used to determine the weight of each criterion. In the third stage, the TOPSIS approach was used to rank alternative solutions to verify the applicability of the evaluation system. Finally, specific development solutions for island investment were proposed. The concepts and methods in this paper are detailed below, and the research framework is shown in Figure 1.

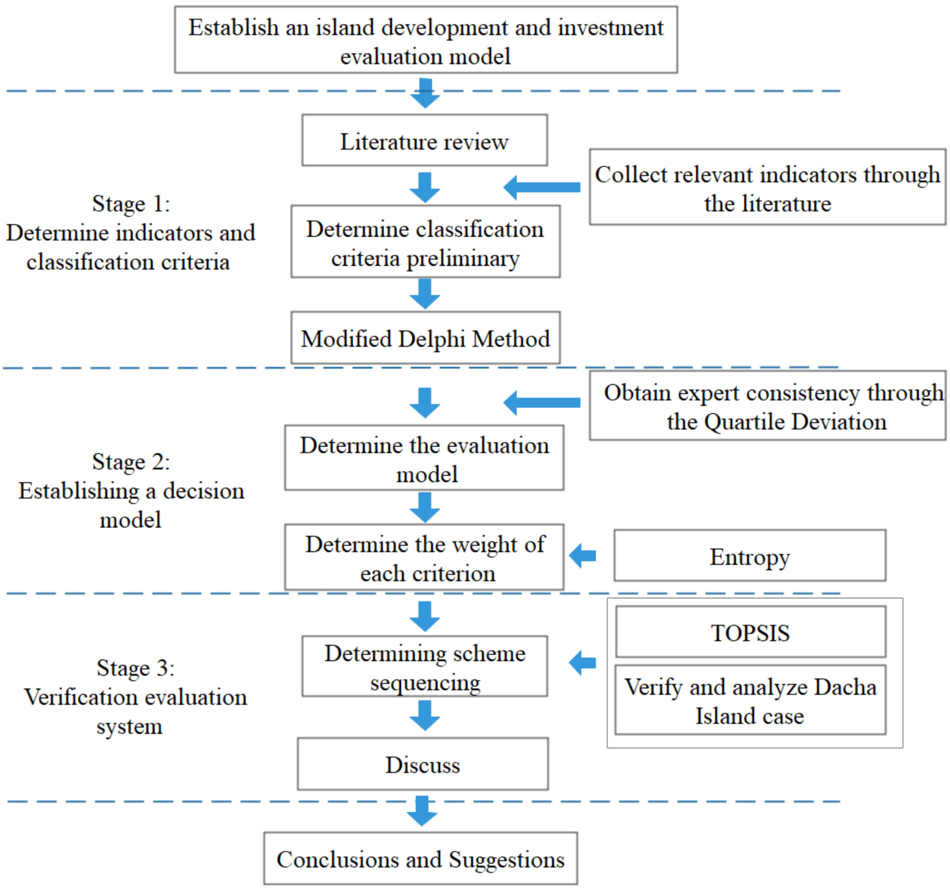

Figure 1. Research framework.

3.1. A Sample Case

Dachan Island (22°30.8′ in north latitude, and 113°50.6′ in east longitude) is located at the mouth of the Qianhai Bay in the estuary of the Pearl River. It belongs to the Nanshan District of Shenzhen. It is the second-largest island in Shenzhen and one of the three Shenzhen islands listed on the first list of uninhabited islands developed and utilized in China. The island is 1.11 km from the shore, with a long coastline of 5.87 km and a land area of 1.2003 km^2. Its highest elevation is 112.8 m and is mainly covered by forests, shrubs, and grass. In addition, there are artificial gardens around the road encircling the island. The GIS map of Dachan Island is shown in Figure 2.

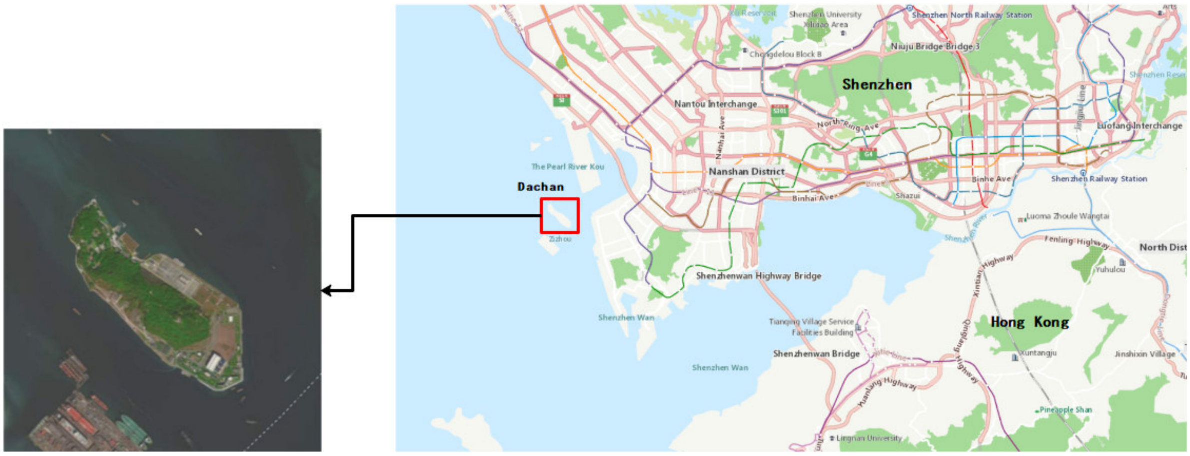

Figure 2. GIS map of Dachan Island.

Dachan Island is located in a special geographical location and is on a golden waterway for small vessels traveling between Hong Kong and mainland China. In July 2018, the State Oceanic Administration (SOA) of the Ministry of Natural Resources of China issued an announcement titled "Guidelines on Paid Use of Sea and Uninhabited Islands". Consequently, three islands of Shenzhen, namely Zhouzai Island, Dachan Island, and Xiaochan Island, have been included on the first list of 60 uninhabited islands that can be developed in Guangdong Province.

At present, Dachan Island is a developed and uninhabited island. There are multiple businesses and government agencies on the island, including Dachan Customs, Youlian Shipyard, and Qianwan Power Plant. These employers occupy a total land area of 618,400 m^2, accounting for 63.7% of the island's total land area. Currently, the island is mainly used for transportation and industrial applications.

In addition, in 2010, China National Petroleum Corporation (CNPC) selected Dachan Island for its Shenzhen liquefied natural gas (LNG) project in the energy industry. In the case of the second-line resource shortage in transporting the gas from western to eastern regions, CNPC can import LNG into the Guangdong Province pipeline network through the LNG project on Dachan Island to meet the market demand. This project also allows CNPC to store and release energy resources to accommodate the peak-to-valley differences in daily market daily demand. However, the reclamation required by this project will have significant negative impacts on the island's surrounding marine environment, marine fishery, and transportation. Therefore, the CNPC LNG project is yet to be approved. In April 2012, it was decided that Dachan island be used only as a gas station and an emergency storage tank in this project.

In the new era of development, Shenzhen has been selected as a socialist pilot demonstration city. Therefore, its surrounding islands have also been given new development requirements and opportunities. Dachan Island has also been actively looking for a new role for development to catch the opportunities in the mainstream of advocating emerging industries.

In the proposal "Planning Optimization of New Centers for Coastal Cities", part of the Baozhong area, Dachan Bay, Dachan Island, and Xiaochan Island have been included in the construction scope of the new central area. In the overall layout plan of "One Bay, Two Mountains, Four Districts, and Four Islands", Dachan Island is targeted to become an innovative cooperation island between Shenzhen and Hong Kong and essentially a free trade port.

According to the actual development status of Dachan Island, the following four investment plans are listed as development options.

(1) Industrial island: The purpose of this option is to build a coastal industrial agglomeration area on Qianhai Bay to help construct a cooperation demonstration zone for the coastal modern marine service industry in Shenzhen.
(2) Shenzhen–Hong Kong innovation cooperation island (i.e., a free trade port): The purpose of this option is to focus on ecological demonstration and Shenzhen–Hong Kong innovation cooperation by building a free trade port.
(3) Transportation island: The purpose of this option is to utilize deep-water shoreline resources of Dachan Island fully and construct a transportation relay port for economic development.
(4) Energy business island: The purpose of this option is to establish an energy relay industry on the island to store and release energy resources.

In this paper, combined with the actual situation of Dacha Island, an island development evaluation system is constructed according to the three stages mentioned above.

3.2. The First Stage: Determining Indicator Categories and Evaluation Criteria

3.2.1. Delphi Method

The Delphi method was initiated by Helmer and Gordon in the 1940s [45,46]. The Delphi method is also known as the expert investigation method. It involves a certain communication method whereby the problems to be solved are sent to the experts for advice; then the opinions of all experts are collected, summarized, and sorted out comprehensively. Then the comprehensive opinions and forecast problems are fed back to each expert, and opinions are solicited again. Each expert revises his/her original opinions according to the comprehensive opinions and then summarizes them. This is repeated many times until the comprehensive opinions of all experts on the problem to be solved tend to be consistent with the decision-making scheme.

Lin and Cho [47] pointed out that the Delphi method is a research method used for technology integration through collecting, analyzing, and evaluating the results given by anonymous experts who communicate on a particular topic via written discussions. Anonymous experts share knowledge, skills, expertise, and opinions until a consensus is reached.

Lin and Cho [47] also summarized the standard operating procedures of a modified Delphi method as follows:

(1) Select relevant anonymous experts to form an expert panel to provide them with a proposed survey outline for a given topic.
(2) Conduct a first-round questionnaire survey by collecting written replies, summarizing them into comparison charts, and deleting the indicators for which consensus was not reached.
(3) Conduct a second-round questionnaire survey by sorting the results of the first-round questionnaires to create a new survey, request the experts to examine their varying opinions, compare them to those of other experts, and revise the opinions.
(4) Conduct a third-round questionnaire survey by using the same approach of the second round.
(5) Consolidate the opinions of the expert panel to form a consensus. If the expert panel does not reach a consensus, Step (3) is repeated until the panel reaches a consensus.

This study adopts the modified Delphi method by using the following steps: (1) Collect relevant literature and preliminarily summarize indicators. (2) Create a modified Delphi questionnaire according to the indicators. (3) Analyze the quartile distribution for each question by comparing the panel's opinions and determining whether they are consistent. (4) Determine the indicators for discussion in the next step and update the questionnaire.

Delphi et al. [48] mentioned that the expert panel in the Delphi method should consist of five-to-nine experts, and each expert's opinions should be collected without interference. Finally, a quantitative method should be used to assess subjective factors objectively.

3.2.2. Determining Sub-Criteria for Island Investment Evaluation Based on the Modified Delphi Method

Step 1: Collect literature.

A large volume of literature and documents related to island development and sustainable development evaluation were collected and sorted before implementing the modified Delphi method. Forty-six second-level evaluation indicators (sub-criteria) were selected according to Dachan Island's characteristics and related policies and regulations.

Step 2: Generate a modified Delphi questionnaire.

The Likert scale was used to evaluate the importance of the indicators, where seven represented "very important" and one represented "very unimportant". A preliminary questionnaire used in an opinion survey was compiled according to the collected indicators. The questionnaire was sent to 15 selected experts coming from industry, academia, and government agencies for a survey. The expert panel consists of seven researchers from the Key Laboratory of Geographic Environment Monitoring of the Natural Resources Department for the Greater Bay Area in Shenzhen University, four experts from the Shenzhen Water Resources Bureau, and four experts from island economic value evaluation agencies. The survey was conducted from March to April 2021, with two rounds of written discussions. After completing the survey, the indicators were summarized and sorted according to expert opinions. The results for the modified Delphi are in Appendix A.

The sub-criteria determined by the modified Delphi method were classified according to their attributes. Figure 3 depicts an evaluation system for the sustainable development of islands. The definitions of the sub-criteria are described as presented below.

The sub-criteria definitions are listed as follows:

(1) Regional gross domestic product (GDP) per capita: the ratio of GDP to resident population in an administrative region in one year.
(2) Regional government resources support the economic and policy support to the island in an administrative region.
(3) Offshore distance: the distance of an island from the inland coastline.
(4) Regional GDP of catering and accommodation: the GDP coming from restaurant and accommodation industries in an administrative region in one year.
(5) Island area: the total area of an island.
(6) Types of natural resources: including water resources, land resources, mineral resources, climate resources, and marine resources.
(7) Types of biological resources: including animal resources, plant resources, and microbial resources.
(8) Coastline length: the total length of an island's coastline.
(9) Surrounding marine environment: the water quality and depth of the sea around the island.
(10) The proportion of natural coastline: the proportion of natural coastline to the total coastline of an island.
(11) Vegetation-coverage ratio: the ratio of forest area to the total island area.
(12) Tourism, leisure, and food industries: the industries supporting tourism, leisure, and other entertainment business.
(13) Transportation infrastructure: the engineering facilities providing transportation services for the production and living on the island.

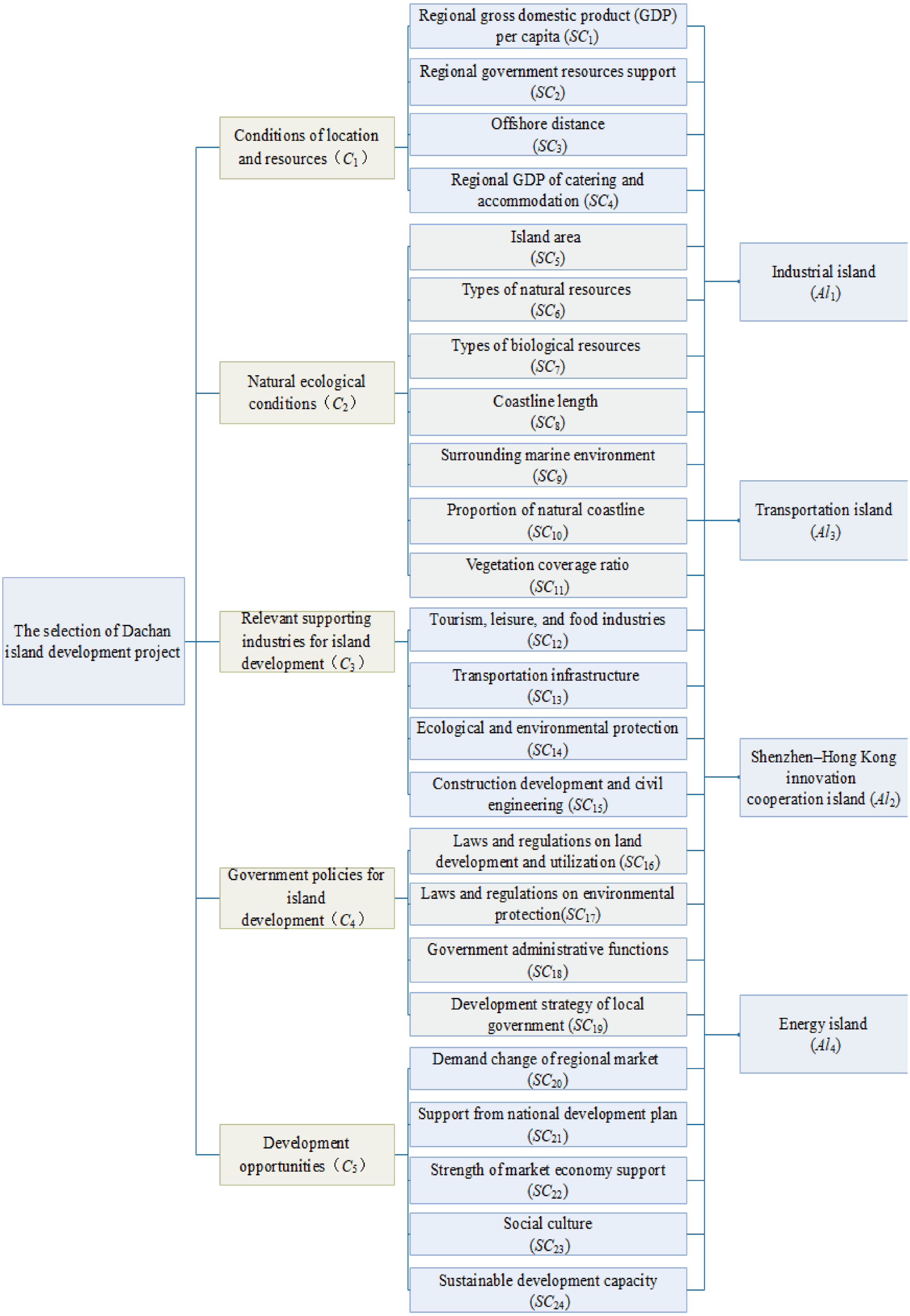

Figure 3. An evaluation system for the sustainable development of islands.

(14) Ecological and environmental protection: the actions taken by the administrative region for protecting the ecology and environment of the island.
(15) Construction development and civil engineering: island infrastructure and housing construction.
(16) Laws and regulations on land development and utilization: laws and policies related to island land development and utilization.
(17) Laws and regulations on environmental protection: laws and policies related to island environmental protection.
(18) Government administrative functions: administrative functions of the local government in island management.
(19) Development strategy of local government: the development plan and strategy formulated by the local government for the region under its jurisdiction
(20) Demand change of regional market: the demand change of consumer groups for consumer products in the region.
(21) Support from national development plan: national planning policy on island development.
(22) Strength of market economy support: the economic support provided by the market for island development and construction.
(23) Social culture: the unique customs and culture of the region.
(24) Sustainable development capacity: the current sustainable development capacity of the island.

3.3. The Second Stage: Weights of Each Sub-Criterion Given by the Entropy Analysis and Decision-Making Model

3.3.1. Entropy

The Entropy model is one of the most widely used MCDM evaluation models. It can be used to estimate the amount of information contained in each piece of data and calculate its weight. Entropy was originally a measure of physical phenomena, referring to the degree of chaos in a given system. A lower entropy value means the molecules are arranged more orderly and closer to perfect crystallization, hence having a greater weight. On the contrary, if the molecules move more irregularly or disorderly, the system's entropy value becomes greater. Entropy can be calculated to determine the relative weights of different attributes. In this study, the weight of each attribute was first calculated to determine its impact on decision-making. Then the weights of all criteria were compared.

The calculation process of the entropy method is as follows [19]:

Step 1: Establish a decision matrix, D, in the following form:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & \cdots & \cdots & C_j & C_n \end{array} \\ \begin{bmatrix} C_{11} & C_{12} & \cdots & \cdots & C_{1j} & C_{1n} \\ C_{21} & C_{22} & \cdots & \cdots & C_{2j} & C_{2n} \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots \\ C_{i1} & C_{i2} & \vdots & \vdots & C_{ij} & C_{in} \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots \\ C_{m1} & C_{m2} & \cdots & \cdots & C_{mj} & C_{mn} \end{bmatrix} \end{array} \tag{1}$$

where $A_1, A_2, A_3, \ldots, A_\mathrm{m}$ stand for expert, and $C_1, C_2, C_3, \ldots, C_\mathrm{n}$ stand for decision criteria.

Step 2: Determine the target attribute, P_{ij}, which is expressed as follows:

$$P_{ij} = \frac{C_{ij}}{\sqrt{\sum\limits_{j=1}^{n} C_{ij}^2}} \tag{2}$$

where $i = 1, \ldots, m$; $j = 1, \ldots, n$. where i is the number of experts, j is decision criterion, and X_{ij} is the evaluation value of the expert i under decision criterion j.

Step 3: Determine E_j to set the weight for each target attribute.

The weight range is $0 \le E_j \le 1$, and k is a positive constant, $k = \frac{1}{lnm}$, where m is the number of experts participating in decision-making.

$$E_j = -K\sum_{i=1}^{m} P_{ij} \ln P_{ij}, \forall j \quad (3)$$

Step 4: Determine d_j.

The result levels of the target attributes are scattered.

$$d_j = 1 - E_j, \forall j \quad (4)$$

Step 5: Identify W_j.

The expected comparative equal weights are as follows:

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j}, \forall j \quad (5)$$

3.3.2. Entropy Analysis

Using the entropy method, the importance criteria provided by the survey experts for each sub-criterion were inputted into Equation (1) to obtain the decision matrix D, and then the target attribute results were inputted into Equation (2) to obtain P_{ij}.

The processed data were successively inputted into Equations (3)–(5) to obtain entropy values, ranks, and weights, as shown in Table 1. Based on the results in Table 1, each sub-criterion was evaluated by summing up and normalization to obtain its weight. The comprehensive evaluation results of each criterion and sub-criterion are shown in Table 2.

Table 1. Results for the entropy model values.

	SC_1	SC_2	SC_3	SC_4	SC_5	SC_6	SC_7	SC_8	SC_9	SC_{10}	SC_{11}	SC_{12}
E_j	0.2717	0.2491	0.2580	0.2828	0.2593	0.2698	0.2595	0.2921	0.2644	0.2686	0.2534	0.2701
d_j	0.7283	0.7509	0.7420	0.7172	0.7407	0.7302	0.7405	0.7079	0.7356	0.7314	0.7466	0.7299
W_j	0.0414	0.0426	0.0421	0.0407	0.0421	0.0415	0.0421	0.0402	0.0418	0.0415	0.0424	0.0415
	SC_{13}	SC_{14}	SC_{15}	SC_{16}	SC_{17}	SC_{18}	SC_{19}	SC_{20}	SC_{21}	SC_{22}	SC_{23}	SC_{24}
E_j	0.2660	0.2611	0.2728	0.2570	0.2781	0.2728	0.2455	0.2601	0.2641	0.2679	0.2623	0.2851
d_j	0.7340	0.7389	0.7272	0.7430	0.7219	0.7272	0.7545	0.7399	0.7359	0.7321	0.7377	0.7149
W_j	0.0417	0.0420	0.0413	0.0422	0.0410	0.0413	0.0428	0.0420	0.0418	0.0416	0.0419	0.0406

Table 2 shows the results for the ranking of sub-criteria in the island evaluation system for development strategies; the importance of the calculated criteria is ranked as follows: SC_{16}, laws and regulations on land development and utilization; SC_{17}, laws and regulations on environmental protection; SC_{21}, support from the national development plan; SC_5, island area; SC_{13}, transportation infrastructure; SC_{14}, ecological and environmental protection; SC_{19}, development strategy of local government; SC_{22}, strength of market economy support; SC_6, types of natural resources; SC_2, regional government resources support; SC_1, regional gross domestic product (GDP) per capita; SC_{15}, construction development and civil engineering; SC_{18}, government administrative functions; SC_3, offshore distance; SC_4, regional GDP of catering and accommodation; SC_{20}, demand change of regional market; SC_{23}, social culture; SC_{24}, sustainable development capacity; SC_7, types of biological resources; SC_8, coastline length; SC_{11}, vegetation coverage ratio; SC_{12}, tourism, leisure, and food industries; SC_9, surrounding marine environment; and SC_{10}, proportion of natural coastline. In the above sub-criteria, the "laws and regulations on land development and utilization" (the 16th sub-criterion) are extremely important for island investment decision-making. This sub-criterion, along with several other key sub-criteria (i.e., the 17th sub-criterion, "laws and regulations on environmental protection"; the 21st sub-criterion, "support from national development plan"; the 13th sub-criterion, "transportation infrastructure"; and the 5th sub-criterion, "island area"), can determine the direction and tone of island development and planning.

Table 2. Weights for the criteria and sub-criteria.

Criteria	Weights	Rank	Sub-Criteria	Weights	Rank
C_1	0.167189	5	SC_1	0.045484	11
			SC_2	0.046087	10
			SC_3	0.037867	14
			SC_4	0.037751	15
C_2	0.260816	1	SC_5	0.047181	4
			SC_6	0.046124	9
			SC_7	0.035814	19
			SC_8	0.034872	20
			SC_9	0.033887	23
			SC_{10}	0.028075	24
			SC_{11}	0.034863	21
C_3	0.173402	4	SC_{12}	0.033921	22
			SC_{13}	0.047152	5
			SC_{14}	0.047113	6
			SC_{15}	0.045216	12
C_4	0.195643	3	SC_{16}	0.05558	1
			SC_{17}	0.047903	2
			SC_{18}	0.045073	13
			SC_{19}	0.047087	7
C_5	0.202949	2	SC_{20}	0.036971	16
			SC_{21}	0.047209	3
			SC_{22}	0.046861	8
			SC_{23}	0.035974	17
			SC_{24}	0.035934	18

3.4. The Third Stage: Use TOPSIS to Select Island Investment Scheme

3.4.1. TOPSIS

Hwang and Yoon [49] proposed the TOPSIS method, where the decision-maker formulated a positive ideal solution and a negative ideal solution, and then calculated the distance between the scheme to be evaluated and the positive ideal solution. The advantage of this method is that the calculated distance can be used as a criterion to compare different schemes. Without using such a distance, when a solution is closest to the positive ideal solution or the furthest from the negative ideal solution, it is difficult to compare. Normalization may affect the diversity of attribute data and further affect the contribution factor of attributes [43]. Hwang et al. [49] pointed out that normalization would affect the contribution factor of attributes and suggested that vector normalization (VN) be taken as the normalization method of TOPSIS method. However, there has also been a replacement of VN with other normalization methods when other researchers use the TOPSIS method, such as Min–Max Normalization (MMN) [50] and sum normalization (SN) [25]. Chen [43] compared the above normalization methods and showed that vector normalization is applicable for TOPSIS method. Therefore, Vector Normalization (VN) was selected in the study when TOPSIS was used. The solution steps are as follows [19,49]:

Step 1: Establish a normalized evaluation matrix.

Use the following equation to establish a standardized evaluation matrix:

$$r_{ij} = \frac{C_{ij}}{\sqrt{\sum\limits_{i=1}^{m} X_{ij}^2}} \tag{6}$$

where i is an alternative scheme, j evaluation criterion, and X_{ij} is the evaluation value of the alternative scheme i under criterion j.

Step 2: Establish a normalized weighted matrix.

Multiply the weights $\sum_{j=1}^{m} W_j(w = (w_1, w_2, \cdots, w_j, \cdots, w_n))$ obtained by the entropy method by the normalized evaluation matrix:

$$V = \begin{bmatrix} V_{11} & V_{12} & \cdots & V_{1n} \\ V_{21} & V_{22} & \cdots & V_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ V_{m1} & V_{m2} & \cdots & V_{mn} \end{bmatrix} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix} \tag{7}$$

Step 3: Determine the positive and negative ideal solutions.

According to the normalized weighted matrix, the positive and negative ideal solutions are derived by using the following equations:

$$A^+ = \left\{ (\max V_{ij} | j \in J), (\min V_{ij} | j \in J'), i = 1, 2, \cdots, m \right\} \tag{8}$$

$$A^- = \left\{ (\min V_{ij} | j \in J), (\max V_{ij} | j \in J'), i = 1, 2, \cdots, m \right\} \tag{9}$$

where J represents a standard related to profit or benefit, and J' represents a standard related to cost or loss.

Step 4: Determine the distances between a solution scheme to the positive and negative ideal solutions.

The separation measures S_i^+ and S_i^- are used to calculate the distances between the solution scheme and the positive and negative ideal solutions, respectively. The distance to the positive ideal solution S_i^+ is calculated as follows:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^*)^2}, i = 1, 2, \cdots, m \tag{10}$$

Similarly, the distance to the negative ideal solution S_i^- is calculated as follows:

$$S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^-)^2}, i = 1, 2, \cdots, m \tag{11}$$

Step 5: Determine the relative proximity C_i^* of the solution scheme relative to the ideal solution. If C_i^* is closer to 1, the evaluated solution scheme is closer to the ideal solution.

$$C_i^* = \frac{S_i^-}{S_i^+ + S_i^-} \tag{12}$$

Step 6: Sort the calculated C_i^* values from high to low to select the best solution.

The TOPSIS method is intuitive and straightforward in decision-making, and therefore, can be easily accepted by decision-makers. Its disadvantage is that the method needs to be combined with other approaches to quantify the indicators for non-quantitative problems. Because the TOPSIS method evaluates solutions from two different perspectives, i.e., from the positive ideal solution and the negative ideal solution, it can avoid the shortcoming of ignoring the needs from different aspects, hence ensuring the best solution. In this study, a weighted method was adopted to obtain objective weights for the indicators from the expert panel. The TOPSIS method was used to conduct the evaluation. By combining the entropy weighting with TOPSIS, this study can quantify the results into objective weights and identify high-weight schemes to find the best investment scheme.

3.4.2. Use TOPSIS to Select Island Investment Scheme

This research proposes the following four candidate schemes for Dachan Island investment planning based on government policies, the local economy, and expert opinions: industrial island (Al_1), Shenzhen–Hong Kong innovation cooperation island (Al_2), transportation island (Al_3), and energy island (Al_4). The decision-makers used the TOPSIS method to select and verify the scheme according to the evaluation criteria:

Step 1: Established a standardized evaluation matrix and a weighted matrix.

First, the experts provided scores for each plan option according to the criteria and created a standardized matrix by using Equation (6). Then the target weights and normalization matrices of all sub-criteria obtained by the entropy method were inputted into Equation (7). The results are shown in Table 3.

Table 3. Normalized decision matrix.

	SC_1	SC_2	SC_3	SC_4	SC_5	SC_6	SC_7	SC_8	SC_9	SC_{10}	SC_{11}	SC_{12}
Al_1	0.017	0.018	0.024	0.020	0.020	0.026	0.016	0.021	0.024	0.019	0.024	0.019
Al_2	0.019	0.024	0.018	0.020	0.019	0.016	0.022	0.021	0.021	0.021	0.021	0.019
Al_3	0.024	0.026	0.019	0.022	0.022	0.021	0.020	0.018	0.017	0.019	0.021	0.018
Al_4	0.021	0.016	0.023	0.019	0.024	0.020	0.025	0.021	0.021	0.024	0.018	0.026
	SC_{13}	SC_{14}	SC_{15}	SC_{16}	SC_{17}	SC_{18}	SC_{19}	SC_{20}	SC_{21}	SC_{22}	SC_{23}	SC_{24}
Al_1	0.021	0.017	0.024	0.020	0.022	0.015	0.019	0.019	0.020	0.021	0.017	0.015
Al_2	0.019	0.018	0.024	0.019	0.024	0.022	0.022	0.019	0.021	0.026	0.024	0.024
Al_3	0.017	0.026	0.017	0.027	0.018	0.023	0.021	0.024	0.021	0.016	0.020	0.022
Al_4	0.025	0.022	0.016	0.018	0.017	0.021	0.024	0.022	0.022	0.019	0.022	0.019

Step 2: Determined S_i^+, S_i^-, and C_i^*.

The adjusted values of the evaluation matrices were substituted into Equations (8) and (9) to obtain S_i^+ and S_i^-. According to Equations (11) and (12), C_i^* was obtained.

Step 3: Determined C_i^* and calculated the priorities of candidate schemes.

The relative proximity C_i^* was obtained by Equation (3). Then the candidate schemes were prioritized to determine the best solution. The results are shown in Table 4.

Table 4. Results of TOPSIS sorting.

	S_i^+	S_i^-	C_i^*	Sorting
Al_1	0.026	0.020	0.429	4
Al_2	0.022	0.024	0.519	1
Al_3	0.022	0.023	0.511	2
Al_4	0.022	0.022	0.494	3

Step 4: Determined the optimized scheme.

The candidate schemes were analyzed and ranked from better to worse, using the decision-making model. The results were as follows: (1) Al_2, Shenzhen–Hong Kong innovation cooperation island (0.519); (2) Al_3, transportation island (0.511); (3) Al_4, energy island (0.494); and (4) Al_1, industrial island (0.429). Finally, the optimized solution was identified as Al_2.

4. Results and Discussion

This paper proposes a multi-criteria decision-making method based on the entropy and TOPSIS methods for island development investment. It aims to comprehensively consider critical indicators, such as island natural resources, ecological environment, economic development level, government policies, and development opportunities. The proposed approach establishes a useful and suitable theoretical framework for island investment and development in China to satisfy the need for efficient economic development and healthy ecological development of coastal islands. Dachan Island in Shenzhen was used as an example to illustrate the application of the quantitative evaluation approach. The decision-making analysis is discussed below.

4.1. Results Analysis of the Evaluation Indicator System

According to the evaluation results of this study, natural ecological conditions have the highest weight (0.260816). Therefore, the most important factor for an island's development is its conditions. Under this criterion, the ranking of the sub-criteria according to weight, from high to low, is as follows: island area, types of natural resources, types of biological resources, coastline length, surrounding marine environment, and proportion of natural coastline. From a long-term development perspective, the island area is an important factor in island development planning because the island area directly determines the economic and ecological value of the island. The second important sub-criterion is the types of natural resources. The purpose of island development is to promote economic development, and natural resources play a strong guiding role in driving the local economy. Therefore, if an island has a good endowment of natural resources, it should be accorded high priority in development planning. The several other previously mentioned sub-criteria rank lower because they reflect the degree of human activity on the island and may change greatly under human intervention.

The criterion of development opportunities has the second-highest weight (0.202949). The ranking of its sub-criteria according to weight, from high to low, is as follows: support from national development plan, strength of market economy support, demand change of regional market, social culture, and sustainable development capacity. Because the country owns uninhabited islands, its development is strongly dependent on national economic development and planning. Moreover, island development requires substantial investment. Therefore, the success or failure of island development also strongly depends on the support of the market economy. The several other sub-criteria mentioned previously rank lower because they mainly respond to the regional market, cultural, and technological abilities. Although they affect island planning and development to a certain extent, their influence is nominal.

The criterion of government policies for island development has the third-highest weight (0.195643). According to weight, from high to low, the ranking of its sub-criteria is as follows: laws and regulations on land development and utilization, laws and regulations on environmental protection, development strategy of local government, and government administrative functions. The premise of island development planning is to determine the island's land-use type. Therefore, island development must be in strict accordance with the relevant land-use laws and regulations. Moreover, island development should not damage the ecological environment. Therefore, the relevant environmental protection laws and regulations should be strictly observed. Furthermore, island development relies on the support of the local government. It should accordingly conform to the local government's development strategy. The government's administrative functions mainly play a supervisory role in island development and have a nominal influence on investment decision-making.

The criterion of relevant supporting industries for island development is ranked fourth in terms of weight (0.173402). These industries are related to the infrastructure and businesses supporting the island's development and planning. The ranking of its sub-criteria according to weight, from high to low, is as follows: transportation infrastructure; ecological and environmental protection; construction development and civil engineering; and tourism, leisure, and food industries. Island development and construction must be supported by good transportation infrastructure. Therefore, this factor is crucial in the supporting industries. Good ecological and environmental protection is conducive to the island's tourism industry. Construction development and civil engineering can help promote island development, while the tourism, leisure, and food industries can create a comfortable lifestyle on the island.

The last ranked criterion is the conditions of location and resources (weight 0.167189). Under this criterion, the sub-criteria are ranked according to weight, from high to low, as follows: regional government resources support, regional GDP per capita, offshore distance, and regional GDP of catering and accommodation. These sub-criteria reflect the construction conditions and economic development of the island. Although good construction conditions and a stable economy can support island construction and development, they weaken the flexibility and necessity of development investment. Therefore, the criterion of conditions of location and resources ranks the lowest.

In general, the five most important sub-criteria in terms of weight are (1) laws and regulations on land development and utilization, (2) laws and regulations on environmental protection, (3) support from the national development plan, (4) island area, and (5) transportation infrastructure.

Among them, the first three sub-criteria reflect the influence of government, which plays a decisive role in decisions on island development. The island area reflects its conditions, which determine its development value. Transportation infrastructure is a supporting industry for island development and plays a promoting and supporting role. In summary, island development firstly depends on government planning and policies, secondly on the island's conditions, and thirdly on supporting industries.

The five least important sub-criteria in the evaluation system are (1) the proportion of natural coastline; (2) the surrounding marine environment; (3) tourism, leisure, and food industries; (4) vegetation coverage ratio; and (5) coastline length. These five indicators do not have strong stability, and human activities can greatly change them. Therefore, island development and planning are less dependent on these indicators.

4.2. Discussions of Scheme Ranking Results

According to the results of the analysis on Dachan Island, the four candidate development plans are ranked from high to low in weight as follows: (1) Shenzhen–Hong Kong innovation cooperation island, (2) transportation island, (3) energy relay island, and (4) industrial island.

There are two reasons to select the first plan as the best option. Firstly, there are strict restrictions on national and local policies. The principle of encouraging innovation and green development has ruled out opportunities for industrial and energy development on Dachan Island. The Shenzhen–Hong Kong innovation cooperation initiative follows this principle very well. Secondly, the Shenzhen Special Economic Zone has economic strength and outstanding innovation capabilities to support the development of Dachan Island in becoming a world-class innovation cooperation island.

There are two advantages at the political level and the economic level. First, Shenzhen is one of the major economic centers in China and a National Independent Innovation Demonstration Zone. It is committed to becoming a global benchmark city. Building Dachan Island to become an innovation cooperation center will help boost China's international image. Second, under the supporting policy of "Regulations of Near Coast Shekou Free Trade Trial Zone in Shenzhen Special Economic Zone", the free trade port on Dachan Island will offer great economic openness. Trade liberalization can effectively improve the economy. Considering the historical experience of other free trade zones, such as Shanghai, the economic development prospects of Dachan Island as a free trade port can exceed those given by the investment planning choices of industrial, energy, and transportation.

Dachan Island is located at the mouth of the Pearl River in the western port area of Shenzhen. It is surrounded by many shipping channels and is close to many container terminals, such as Dachan Bay, Chi Bay, and Shekou. Therefore, it has the potential to be a traffic relay station. However, as the largest ship-repair base in Asia, the shipping activities of Mazhou Island would be negatively affected by Dachan Island if Dachan were developed as a transportation island. Developing Xiaochan Island, which has similar shipping conditions, to become a transportation island can avoid such a conflict and increase the islands' utilization value.

If Dachan Island were developed to build an energy relay island with a project such as the CNPC LNG, it would conflict with the ship repair business of Youlian Shipyard on Mazhou Island because open fire operation is strictly prohibited within 400 m.

Island industrialization may seriously affect the marine ecological environment. Mazhou Island was developed for industrialization and offered a serious lesson and warning for future island development.

In summary, developing Dachan Island to become a Shenzhen–Hong Kong innovation cooperation island can avoid the disadvantages of developing industrial, energy, and transportation businesses and offer unique advantages. Such a development scheme is the best plan and can offer the greatest value to Shenzhen.

4.3. Discussion

This study constructs an island development evaluation solution with both economic and ecological aspects through multi-criteria decision-making. By comparison, the results of this study are consistent with the actual development direction of Dachan Island. Therefore, it is concluded that the evaluation system proposed is practical and worth promoting. The advantage of the island development evaluation system constructed in this study is that it integrates economic indicators and ecological indicators to effectively enhance the sustainable development ability of island development on the basis of previous research. It is a set of scientific and practical evaluation systems. This study further improves the evaluation system of island development and provides a reference for others. Secondly, island development and investment is a large-scale investment scheme. As for the multi-criteria decision-making of large-scale investment schemes, the Entropy and TOPSIS model can effectively solve the sustainable development problem of island development, as demonstrated by the case of Dachan Island. Although the evaluation index of the system is obtained by experts, which has the shortcomings of subjectivity, the Delphi method can effectively improve the practicability of the model. Therefore, a model based on Entropy and TOPSIS combined with multi-criteria decision-making can be applied to large investment cases, such as the evaluation plan of the island investment, and the model is worth promoting. Entropy and TOPSIS multi-criteria decision-making model has the advantage that the method of group decision method by integrating the opinions of the experts to conclude the final decision. This method cannot only take the quantitative indicators based on data as the modeling basis, but also take into account the qualitative indicators on this basis, so it can make the evaluation system constructed more comprehensive and more scientific. It can provide research ideas for solving other large-scale investment cases.

It can be concluded from the above evaluation index system that the important first-level index for island development is the natural ecological condition of the island, which is the basis for island development and plays a decisive role in the sustainable development of the island. The secondary indicators are laws and regulations of land development and utilization, laws and regulations of environmental protection, support of national development plan, and island area. Compliance with land development and environmental protection standards is a prerequisite for the construction of sustainable islands, and the approval and support of national development plans is a necessary condition for enhancing the sustainable development of islands. Island area largely determines the ability of island sustainable development, so it can be said that the above indicators have a relatively great impact on it. Therefore, the five aspects mentioned above should be taken into account in making plans for the sustainable development of islands.

5. Conclusions and Suggestions

This study analyzed investment choices in island planning. To this end, an island investment evaluation system was developed based on MCDM, using entropy and TOPSIS, and there was a comprehensive consideration of various factors, such as natural resources, ecological environment, economic level, government policies, and development opportunities. Dachan Island was analyzed as an example for verification analysis. In this regard, the results of the analysis show that, in its development plan, Dachan Island should be prioritized as an innovation cooperation island between Shenzhen and Hong Kong. The evaluation system developed in this paper offers consistent analytical results with the actual development scheme. Therefore, the validity of the evaluation system is verified. This model can be used to evaluate investment planning for coastal islands in China and provide guidance for the decision-making of governments and enterprises. The suggestions in this study are divided into two parts, namely (1) suggestions for the future sustainable development of islands and (2) suggestions for future research, as described below.

(1) Suggestions for the future sustainable development of islands:

The sustainable development of islands is the focus of the government, and the development of islands should follow scientific advancement. For decision-makers, the development of enhancing the sustainable development of islands should first follow the laws and norms of land development and utilization and environmental protection. Environmental laws and regulations have a direct impact on the realization of sustainable development. As a consequence, in the process of island development, it is suggested to take laws and regulations into account to regulate the development of islands. Within the scope of national support and permission, overall and long-term planning should be carried out on the use area of islands based on their own natural ecological conditions, including natural and biological resources, and the characteristics and advantages of the islands themselves.

Relevant authorities, enterprises, and the public should take an active part in the sustainable development of the island. In terms of the government concerned, the development of islands will inevitably bring about population changes and production activities. Measures such as promoting the compact development of island cities, improving the intensive use of resources, encouraging low-carbon production, and building convenient public facilities can effectively alleviate the environmental pressure caused by population change [51]. Enterprises should improve energy utilization efficiency through technological innovation, such as improving energy-processing technology in energy-intensive industries, enhancing industrial technology intensification, and promoting energy-saving technology reform in the production process. As for the public, with the improvement of people's income level, people have higher and higher requirements for the quality of the living environment. At the same time, people's public quality and environmental awareness are also improved, so the concept of sustainable development is promoted and the residents are encouraged to actively participate in planning. These methods are conducive to maintaining the sustainable development capacity of the islands [52].

(2) Suggestions for future research:

The island evaluation system proposed in this study includes qualitative and quantitative indicators. Since there are no historical data before the formulation of the island development plan, it cannot provide an accurate reference for the formulation of the plan on quantitative indicators. However, after the completion of the island scheme, relevant quantitative indicators will produce data. Therefore, in future studies, researchers can collect and sort out the quantitative indicator data of the completed island. On the one hand, the optimal island assessment solution can be constructed by using statistical methods based on the actual data produced by quantitative indicators. On the other hand, the quantitative index data involved in this study can also be substituted into the evaluation system to test the comprehensiveness and applicability of the evaluation system determined by the model and analyze the advantages and disadvantages of the model through actual data, so as to improve the island development evaluation system.

Secondly, there are various ways to solve the multi-criteria decision-making problem. Although the multi-criteria decision-making method of Entropy + TOPSIS is widely used in large investment scenarios [53,54], there may be more suitable solutions that provide better solutions for island investments as time goes on and actual conditions alter. For example, as mentioned above, an optimized island investment evaluation model can be constructed by using a problem-mechanism analysis and data analysis based on subsequent data. An evaluation preference model can be established by converting evaluation indicators into objective function or heuristic information. Hence, further research is needed to improve the evaluation system of island development.

Finally, similar to most methods in MCDM, the TOPSIS method has the Problem of Rank Reversal Problem [55]. In the case adopted in this study, the alternative was already determined by the development status of the island, so the impact of the decision change was not further studied. Nevertheless, with the actual development of islands, the location of islands will also change, so the COMET method and SPOTIS method can be used to conduct in-depth research on the location of island sustainable development.

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Appendix A

The appendix is carried out in two rounds of modified Delphi questionnaire surveys. The consensus was analyzed for each indicator based on expert opinions and the calculation results of the quartile difference.

Table A1. Results for the modified Delphi method.

		Results of the First Round			Results of the Second Round		
Items	**Indicator**	**Average Value**	**Quartile Deviation**	**Consistency**	**Average Value**	**Quartile Deviation**	**Consistency**
1	Laws and regulations on land development and utilization	5.20	0	√	5.27	0	√
2	Laws and regulations on environmental protection	5.93	0	√	6.00	0	√
3	Support from national development plan	5.07	0	√	5.13	0	√
4	Island area	5.07	0	√	5.13	0	√
5	Transportation infrastructure	5.13	0	√	5.20	0	√
6	The time to get to the island	6.00	2	×			
7	Ecological and environmental protection	5.13	0	√	5.20	0	√
8	Popularity of the island	2.73	2	×			
9	Demand from overseas market	4.13	0	√	4.20	0	
10	Development strategy of local government	5.07	0	√	5.13	0	√
11	Strength of market economy support	5.20	0	√	5.27	0	√
12	Types of natural resources	6.47	0	√	6.53	0	√

Table A1. *Cont.*

		Results of the First Round			Results of the Second Round		
Items	**Indicator**	**Average Value**	**Quartile Deviation**	**Consistency**	**Average Value**	**Quartile Deviation**	**Consistency**
13	Island elevation	3.93	0	√	4.00	0	
14	Regional government resources support	6.00	0	√	6.07	0	√
15	Freshwater resources	2.13	2	×			
16	Regional gross domestic product (GDP) per capita	5.87	0	√	5.93	0	√
17	Strength of environmental protection support	3.6	0	√	3.67	0	
18	Construction development and civil engineering	5.07	0	√	5.13	0	√
19	Historical culture and relics resources	6.07	1	×			
20	Wind frequency for the whole year	3.80	1	×			
21	The ability to supply water and electricity	3.53	2	×			
22	Government administrative functions	5.07	0	√	5.13	0	√
23	Offshore distance	5.87	0	√	5.93	0	√
24	Regional GDP of catering and accommodation	5.80	0	√	5.87	0	√
25	Geology and geomorphology	4.47	3	×			
26	Safety of islands	6.13	1	×			
27	Demand change of regional market	5.73	0	√	5.80	0	√
28	humidity	3.53	0	√	3.60	0	√
29	Social culture	6.00	0	√	6.07	0	√
30	Type of soil	4.07	0	√	4.13	0	
31	Sustainable development capacity	4.53	0	√	4.60	0	√
32	temperature	4.87	0	√	4.93	1	
33	precipitation	4.00	0	√	4.07	0	
34	Types of biological resources	5.87	0	√	5.93	0	√
35	Coastline length	5.73	0	√	5.80	0	√
36	Types of tidal flats	3.13	0	√	3.20	0	
37	Sea-level rise	5.20	2	×			
38	Status of reclamation	5.87	2	×			
39	Vegetation coverage ratio	5.00	0	√	5.07	0	√
40	Tourism, leisure, and food industries	5.07	0	√	5.13	0	√
41	Surrounding marine environment	5.93	0	√	6.00	0	√
42	Density of organisms	3.07	0	√	3.13	0	

Table A1. *Cont.*

		Results of the First Round			Results of the Second Round		
Items	**Indicator**	**Average Value**	**Quartile Deviation**	**Consistency**	**Average Value**	**Quartile Deviation**	**Consistency**
43	National defense security	5.93	2	×			
44	Proportion of natural coastline	5.20	0	√	5.27	0	√
45	Erosion and collapse of the coast	2.60	3	×			
46	Air quality	4.87	2	×			
47	Comfort of climate	6.27	1	×			

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