



Photovoltaic Charging Station Site Selection using a Multi-Criteria Decision Making (MCDM) Framework with a Novel Criterion Identification

Abedallah Z. Abualkishik * , Rasha Almajed

American University in the Emirates, Dubai, UAE

Emails: abedallah.abualkishik@aue.ae; rasha.almajed@aue.ae

Abstract

Charging points on islands are becoming highly essential due to growing environmental concerns and an increase in the number of electric ships that need to be recharged. Site choice is the first step, but there is not enough research on island photovoltaic charging station site selection (IPVCS). To select the best IPVCS site, a multi-criteria decision-making framework (MCDM) is proposed. As a result of this structure, a new set of criteria for evaluating ships is formed, and current criteria are used to suggest two new ones: "Likelihood of adverse weather" and "Charging distance of the ship." Simultaneously time, the correlation among criteria is shaky at best. Therefore, the weight of the criteria is determined first. Then the rank of the alternatives is computed by the simultaneous evaluation of criteria and alternatives (SECA). Multi-criteria techniques like SECA may be used to objectively and accurately determine the weights of criteria. The best alternative is PVC₃ followed by PVC₁ then PVC₂ then PVC₄.

Keywords: Photovoltaic; MCDM; SECA; IPVCS; decision-making; site selection; Charging

1. Introduction

China is a country that is surrounded by water, and it has a large number of islands. Islands are rich in both land and river assets because they serve as a bridge between land and sea. Suggestions like "becoming a maritime power" and "the ocean is a corporate strategy place for high-quality advancement" have been put forth since China's 18th National Congress of the Communist Party of China (CPC) was held in 2012. China's ocean development is now in a new phase. With a coastline of 4.7 million square kilometers, China is one of the world's most powerful maritime nations. Only 801 of China's 11,000 islands have access to electricity, as shown in the 2017 Survey Bulletin of Islands, and the advancement is less than 10%. (Department of Natural Resources, 2018). Marine tourism, commerce, navigation, science, and other fields rely heavily on islands (organizations) for their preservation and growth of maritime needs and privileges. Islands (organizations) play an important role in all of these areas. Marine advancement is being stifled by the islands' lack of electricity[1].

The maritime business has grown as a result of the increasing construction and use of islands. The dumping of wastes into the oceans, although encouraging the growth of the marine market, also has a detrimental influence on the natural marine ecosystem. A third of China's air pollution comes from ships, and the environmental damage they cause cannot be ignored [2]. All-electric sails have taken the lead in the construction of ships in the future because of their environmental and energy-saving qualities [1]. Electric ships, on the other hand, face a major challenge in extending their range due to a lack of charging infrastructure. Long-distance transport of electric ships is impossible due to their reliance on battery power. Ocean transport will be feasible if the island's electric supply can be

augmented. Shipping can be made more efficient and cleaner, while also reducing pollution and protecting the environment if electric ships are used.

In order to charge on the island, charging channels must be built and the island's generator must be used. Ocean-going islands currently rely primarily on diesel oil for their power generation, which contributes to environmental pollution [3]. Nitrogen oxides, sulfur oxides, particulates, and a lot of carbon dioxide are all damaging to the environment when diesel generators are used. Environmental damage must be addressed to help reduce the greenhouse effect. Photovoltaic solar production has been widely discussed to minimize energy use and carbon emissions pollution. Oil and gas can be found in offshore islands and their adjacent seas. Renewable energy sources such as wind, solar, wave, and hydropower are infinite and can be produced on-site. Even if it doesn't save money or resources, it can also help reduce pollution. PV is a low-cost, environmentally friendly source of energy [3]. Solar PV power generation that is safe, reliable, noise-free, pollution-free, and environmentally friendly is thriving. On the other hand, offshore PV panels can minimize sand on the frames, which results in a higher output of electricity than seawater PV panels. In addition, PV electricity production is highly susceptible to weather conditions, which makes it volatile and inefficient[4]–[6].

As a result, to assure the reliability of PV power plants, ESSs are installed and the energy infrastructure is linked. It is possible to supply power shortages for electric ships by using battery storage (ESS) or purchasing electricity from the power network. It also minimizes the quantity of energy that must be imported, which saves money on electricity purchases. As for the use of photovoltaics, researchers have already researched flat bridge PV panels, but there are few studies on the building of island PV charging points. This is due to the lack of research on the building of island PV charging points.

Figure 1 shows that the PV panels on the floating bridge are in use [7]. The floating bridge PV panels have also been studied by many scholars in the past. Proposed floating bridge PV panels on the water are evaluated economically by [7]. However, the oceans are ignored in favor of lakes and reservoirs. A study by [8] examined the potential of integrating flat-panel PV systems with established fossil fuel power plants. Despite this, flat bridge PV panels create less energy than centralized PV powerplants due to the effects of crashing waves.



Figure 1: PV panels.

Wu et al. [9] conducted a risk assessment for an offshore Power generating project and made recommendations based on their findings. These dangers can be managed to avoid in the planning purposes of island PV powerplants, and the framework can also serve as a basis for future research in this area. Optimized the island's hybrid energy system, which included a diesel generator, PV panels from the solar array, and a wind turbine, as well as the location of the system. PV power plants can generate more electricity and reduce the amount of energy needed to move it around. However, the PV charging station differs from either the Pv power plant in that it has a different

design. Research into the number and location of PV charging stations is necessary, but not the power station itself. PV charging stations have been extensively studied[7]–[10] whereas IPVCS have received only a few studies to date. IPVCS can power battery-powered ships passing thru the island and decrease the island's reliance on non-renewable energy.

Site choice is the first step in the construction of the IPVCS. For island PV power stations, researchers have carried out a few investigations on the placement and scale of an incorporated energy system containing a PV system, windmill, and power storage technology, such as Singh et al. [11]. Aside from mentioning site selection, there was no in-depth study or specific strategies for site choice in the paper. The location of a PV charging station has been thoroughly studied by several academics [11]–[13][1], [11], [14]–[16].

However, their research did not consider the unique characteristics of islands and electrical ships. The ship is unable to dock, hence the fueling distance is considerable. There are just a few studies that address IPVCS choice of location. He (2018) researched how to choose the best location for a battery-powered ship charging point and how to estimate its capacity. The method was used to identify the optimum site choice and capabilities dedication scheme to minimize starts to decline under the presumption that a specific number of required to charge piles would be constructed. To select the best location, the system network loss at each of the selected nodes is calculated and the location with the smallest system network team loss is chosen. The author, on the other hand, only considers quantitative criteria, including solar radiation, and does not take into account qualitative data like this.

Qualitative factors, such as traffic convenience, building requirements, the environment, and so on, must be taken into account. Choosing only based on qualitative criteria will lead to a biased outcome. The MCDM framework proposed in this research is distinct from previous studies, which only addressed quantitative criteria.

The IPVCS site choice is done by an MCDM methodology. PV power production projects are expanding in China at the moment because of the country's emphasis on sustainable power. PV charging stations on islands, on the other hand, have received very little research attention. When it comes to selecting a location for IPVCS, the MCDM framework takes into account not only quantitative factors but also qualitative ones, which makes the system more realistic.

The remainder of the paper will be outlined: There is a literature review in the second part, a methodology in the third part a case study in the fourth part, a conclusion, and future work final part.

2. Related Work

The placement of a PV power plant and a charging station is now the subject of several studies, with some researchers even combining the two. When deciding where to put PV charging points and power plants, it's important to take into account not only the financial aspects of construction and operation but also the social and environmental ramifications, such as local regulations and pollution. There are also significant discrepancies in the assessment indices for PV power plants compared to charging stations. Chargers must take into account technical aspects like power consumption, fueling distance, and grid connection range whereas PV power plants concentrate on natural elements like sunlight quantity and temperature.

Islands, unlike the rest of the country, are vulnerable to the weather. In addition to limiting the output of PV panels, inclement weather will also have an impact on the sailing of electric ships, reducing the efficiency of IPVCS. It's important to factor in the 'Probability of severe weather,' then. It's also worth noting that although electric automobiles may be recharged at stations, electric ships can only be recharged on shore. Charge distance for electric ships must be taken into account since the cost and energy loss rise with the growth in charging range. As a result, two more criteria are needed.

AHP, expert questionnaire survey, entropy weight method, PCA technique, etc., are all ways of calculating positivist and interpretivist weights, although AHP and volatility weight method are the two most often used approaches. To identify the PV power plant, Ozdemir and Sahin [15] used AHP. The fuzzy-based weight approach was utilized by Jenifer and Jha [17] to improve the supply chain. AHP is a simple and easy strategy, but it has a lot of subjectivity since it emphasizes subjective

aspects and takes into account the thoughts of decision-makers. In an objective weighing approach, the entropy weight method is both objective and logical.

Using a mix of AHP and entropy weighting, the criterion weight is more appropriate since it takes into account both subjective and objective elements. Currently, several studies combine the AHP and entropy weight approach to establish the criterion weights. Using the AHP and entropy weighting approach, [18] evaluated the security level of the power grid. The use of entropy weights and AHP to find the saltwater hydro storage facility was done by Zhang [19]. Analyzing the groundwater using the AHP and entropy technique was done by [17]. It was found that the AHP and entropy methods were utilized to assess urban green transport design by Ma et al. [20].

The PV power station's placement is an MCDM issue.

The MCDM approach is used by certain researchers to analyze the choice of location. AHP and MCDM were utilized by [21] to determine the best placement for a photovoltaic power plant. The hydropower plant was located by Rana and Patel [22] using AHP, WPM, and TOPSIS algorithms. ELECTRE-II technique used by [23], [24] to solve placement of PV power station project. Using fuzzy ANP-VIKOR for big commercial roof PV systems, Wu et al., [25], proposed a placement framework for such systems. PROMETHEE was used as an MCDM framework for shading PV devices by [26]. When Wu and his colleagues [27] used the TODIM approach, they were able to pinpoint the PV power production.

There are no vetoing factors in this paper's system, hence the ELECTRE-II algorithm can't be used. PROMETHEE and TODIM fail to account for both the group's benefit and the individual's sense of loss [9], [25]. If the ship's charging distance and the power system distance conflict, the best option is to choose a technique that is as near to perfect as possible.

The TOPSIS and VIKOR methods, which are both used to rank criteria, get the closest to the optimal answer. Along with the ranking, the VIKOR technique offers an advantage rate-based compromise solution [28]. As a result, the candidate positions in this study are ranked using the VIKOR approach.

A complete assessment criteria system must be established, encompassing both qualitative and quantitative factors, to choose the best site for the IPVCS. There are also two new ones based on current ones: a possibility of harsh weather conditions and a ship's charging range. The criterion weight is determined using a SECA weight technique. This study used the SECA approach to deal with the conflict among criteria and rank alternatives.

3. MCDM Framework

SECA, established by Keshavarz-Ghorabae et al. [29], can balance assessment methods objectively without subjective judgments, despite the necessity for parameters to be defined. In this way, professionals can make more accurate conclusions, which is the primary benefit of objective assessment standards. Figure 1 shows the framework of this study. The following are the main stages in the SECA method

Following these steps, a multi-objective non-linear programming model was established and the outcomes were interpreted:

- (1) a criteria set was established, and
- (2) suitable alternatives for wastewater allocation were identified;
- (3) a judgement matrix was established and ended up scoring by experts; and
- (4) the final allocation of photovoltaic was determined.

The contribution of this work is the creation of SECA multi-criteria decision-making approach to identify the optimal wastewater allocation choice. The key aspects of the SECA approach are (i) the use of a multi-objective non-linear programming to rank the importance of criteria and alternatives simultaneously, and (ii) the elimination of the requirement to weight the criteria individually. This programming paradigm is based on the principle of minimising the spread of criteria weights around their reference points in order to optimise the actual quality of alternatives. The decision-making matrix's anchor points are determined by a combination of the standard error and relationship between data points within and across criteria.

Several Multi-Criteria Decision-Making (MCDM) systems, such as AHP, VIKOR, TOPSIS, and so on, have been created, each with its own unique approach to the problem of allocating wastewater.

In general, Multi-Criteria Decision-Making (MCDM) approaches may be broken down into two subsets: Multi-Attribute Decision-Making (MADM) is used to choose the most optimal option, whereas MODM is used to pick the most desirable alternatives. The MADM techniques are used to assess discrete variables. Given that the panel of experts has a role in the first stage of the process—determining the criteria weights—these techniques are a priori and process-based. The MODM approaches are used to produce a continuous collection of solutions considering diverse criteria. These approaches are a posteriori, since the professionals take part in the final phase of the choice of the best solution.

In light of this, the primary difference between both the SECA approach utilised in this research and the MCDM approaches used in previous studies is the incorporation of the MODM framework. In prior research, MADM techniques were used to pick the best option or in other situations, optimization models were utilised to produce workable alternatives and then MADM techniques were employed to determine the best alternative. However, the SECA technique optimises a solution while ranking options concurrently.

Keshavarz-Ghorabae et al. created a multi-objective non-linear computational formula to rank and weight criteria at the same time. The model's goals were to maximise the alternatives' combined performance, minimise the model's objective criteria weights' departures from the point of reference based on information about within-criterion variation, and minimise the model's criterion weights' departures from the point of reference utilizing data about among variation.

The judgement matrix data is used to provide a weight to each criterion in the SECA inter judgement approach. The standard error and correlation indices, two important concepts in statistics, are used here. In mathematics, the standard error index represents data dispersion; in MCDM approaches, it's utilised to determine the relative brightness of the alternatives' interactions across criteria. The correlation index measures the linear strength of a link between two variables, and it's used in multi-criteria decision-making (MCDM) approaches to determine how much of a tension exists between both the criteria.

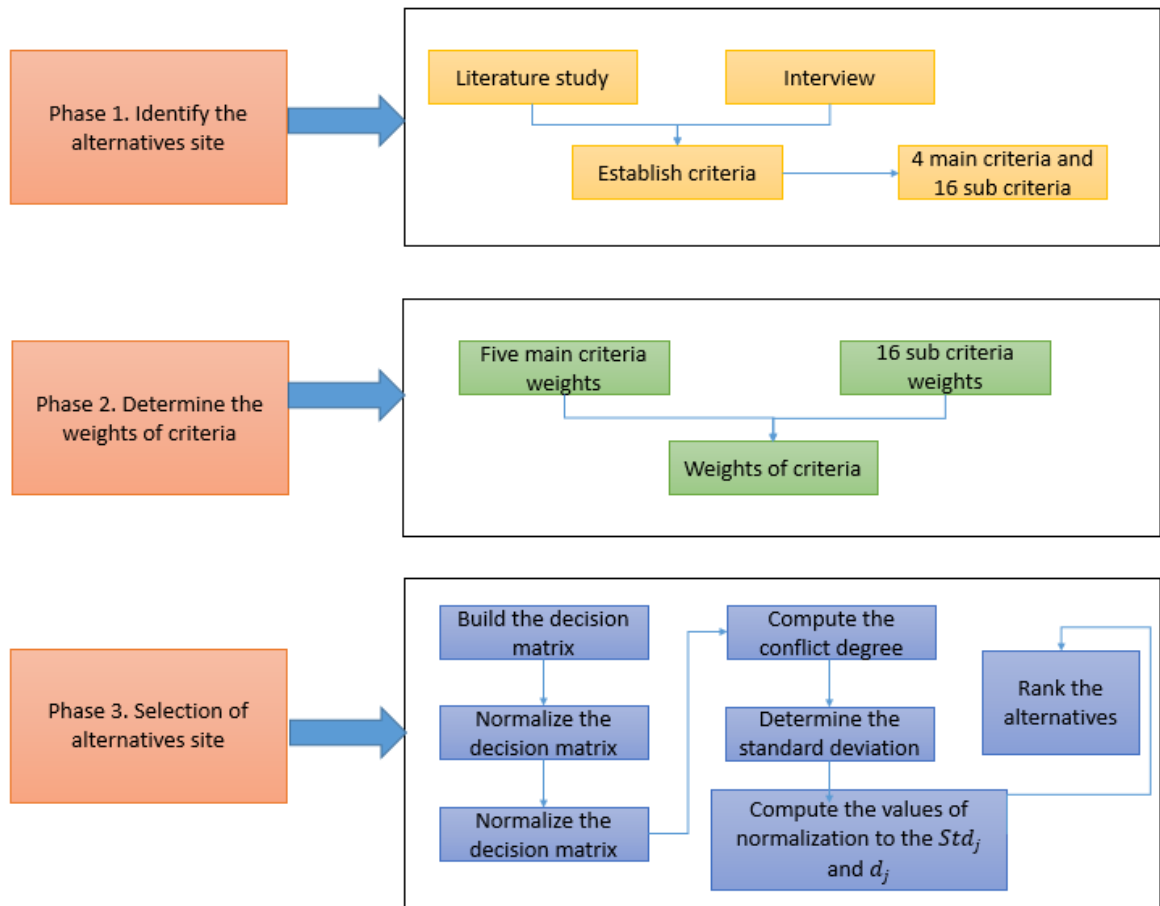


Figure 2: The framework of this study.

Step 1: Build the decision matrix: the initial decision matrix is built first by

$$X = \begin{bmatrix} x_{11} & \dots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \dots & x_{nm} \end{bmatrix} \quad (1)$$

Where n refers to the number of alternatives and m refers to the number of criteria. x_{ij} refers to the preference value of criteria and alternatives where $i = 1,2,3 \dots n; j = 1,2,3 \dots m$

Step 2: Construct the normalization matrix by the aggregated decision matrix from the previous step

$$x_{ij}^N = \begin{cases} \frac{x_{ij}}{\max x_{ij}}; & \text{if } x_{ij} \text{ is a beneficial criteria} \\ \frac{\min x_{ij}}{x_{ij}}; & \text{if } x_{ij} \text{ is a cost criteria} \end{cases} \quad (2)$$

$$X = \begin{bmatrix} x_{11}^N & \dots & x_{1m}^N \\ \vdots & \ddots & \vdots \\ x_{n1}^N & \dots & x_{nm}^N \end{bmatrix} \quad (3)$$

Step 3: Compute the conflict degree

$$d_j = \sum_{i=1}^m (1 - C_j) \quad (4)$$

Where C_j refers to the correlation between j th and columns of normalization value

Step 4: Determine the standard deviation

$$Std_j = \sqrt{\frac{x_{11}^N - \bar{x}_{11}^N}{n}} \quad (5)$$

Step 5: Compute the values of normalization to the Std_j and d_j

$$Std_j^N = \frac{Std_j}{\sum_{i=1}^m Std_j} \quad (6)$$

$$d_j^N = \frac{d_j}{\sum_{i=1}^m d_j} \quad (7)$$

Step 6: The model of non-linear is solved by the multi-objective as

$$\max S_i = \sum_{j=1}^m w_j x_{ij}^N \quad (8)$$

$$\min A_b = \sum_{j=1}^m (w_j - Std_j^N)^2 \quad (9)$$

$$\max R_c = \sum_{j=1}^m (w_j - d_j^N)^2 \quad (10)$$

s.t.

$$\sum_{j=1}^m w_j = 1 \quad (11)$$

$$w_j \leq 1, j = 1, 2, \dots, m$$

Step 7: Optimize the previous model as

$$\max Z = S_i - \beta(A_b + R_c) \quad (12)$$

S.t.

$$S_i = \sum_{j=1}^m w_j x_{ij}^N \quad (13)$$

$$A_b = \sum_{j=1}^m (w_j - Std_j^N)^2 \quad (14)$$

$$R_c = \sum_{j=1}^m (w_j - d_j^N)^2 \quad (15)$$

$$\sum_{j=1}^m w_j = 1 \quad (16)$$

$$w_j \leq 1, j = 1, 2, \dots, m$$

4. MCDM Application

In this part, the MCDM methodology for site location of IPVCS based on new criterion identification is applied to an example.

For example, imagine that China built a PV power station on an island to power ships. A committee made up of the three experts is to be formed. Using the satellite, traffic, and grid maps, as well as conducting a thorough investigation, PVA₁, PVA₂, PVA₃, and PVA₄, were initially selected as the four options. Table 1 list the credentials of the three expert's values.

In this study. We used four main criteria, 16 sub-criteria, and four alternatives as the below figure

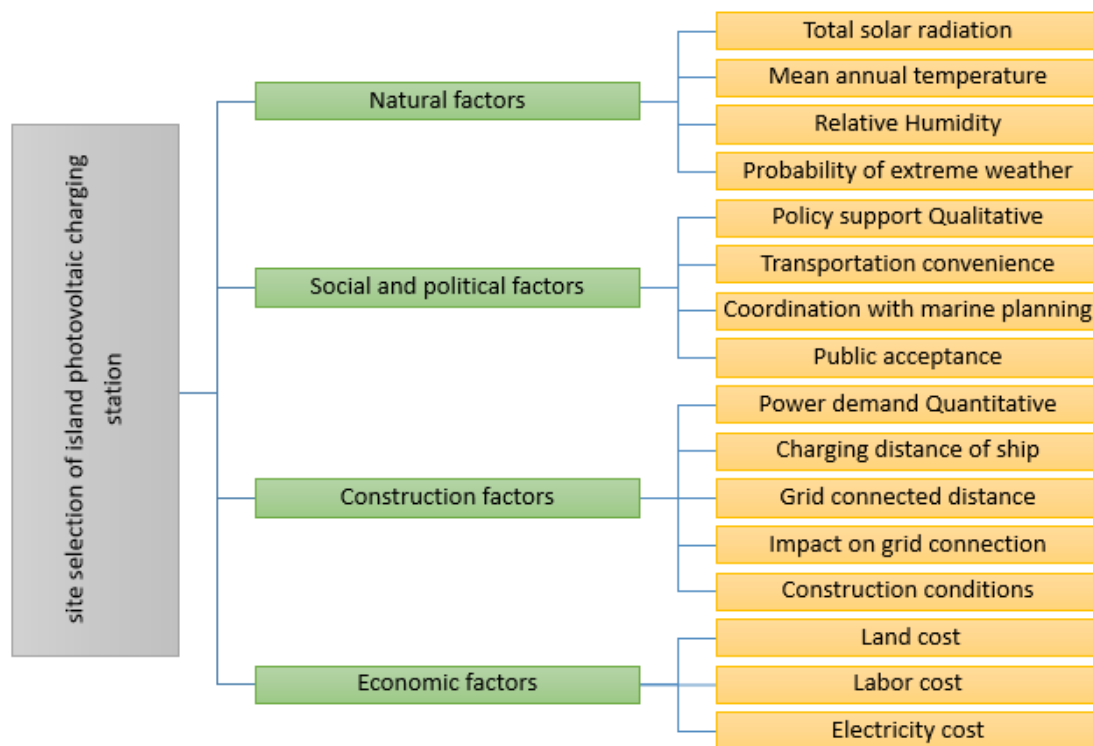


Figure 3: Normalization factors

This study proposes an assessment criterion system that includes six quantitative and nine qualitative factors. A committee graded the qualitative data while the National Bureau of Statistics and China Meteorological Network collected the numeric data. Table 2 shows that aggregated matrix of the four choices.

Table 1: The values of the candidate.

	PVC1	PVC2	PVC3	PVC4	PVC5	PVC6	PVC7
PVA1	90	40	17	50	90	70	70
PVA2	70	70	50	70	90	70	70
PVA3	50	17	50	50	70	50	90
PVA4	-	-	-	-	-	-	-
	PVC9	PVC10	PVC11	PVC12	PVC13	PVC14	PVC15
PVA1	40	40	50	70	40	90	40
PVA2	17	50	90	50	40	70	50
PVA3	17	90	50	90	70	70	50
PVA4	70	90	70	40	90	50	70
	PVC1	PVC2	PVC3	PVC4	PVC5	PVC6	PVC7
PVA1	90	50	90	50	50	40	90
PVA2	90	90	40	17	50	40	40
PVA3	90	70	90	90	70	90	17
PVA4	50	50	90	40	70	90	70
	PVC9	PVC10	PVC11	PVC12	PVC13	PVC14	PVC15
PVA1	70	50	70	90	70	40	90
PVA2	50	70	40	40	40	17	50
PVA3	40	90	40	70	70	17	90
PVA4	70	40	40	90	40	50	70
	PVC1	PVC2	PVC3	PVC4	PVC5	PVC6	PVC7
PVA1	50	70	50	40	50	70	50
PVA2	70	17	50	90	70	90	40
PVA3	90	70	90	40	40	50	17
PVA4	90	90	50	70	50	90	50
	PVC9	PVC10	PVC11	PVC12	PVC13	PVC14	PVC15
PVA1	50	17	70	70	50	90	90
PVA2	40	70	40	40	90	70	70
PVA3	70	70	40	40	90	50	50
PVA4	90	90	17	90	70	40	17

Table 2. The aggregated values of the candidate.

	PVC1	PVC2	PVC3	PVC4	PVC5	PVC6	PVC7	PVC8
PVA1	76.66666667	53.33333333	52.33333333	46.66666667	63.33333333	60	70	63.33333333
PVA2	76.66666667	59	46.66666667	59	70	66.66666667	50	52.33333333
PVA3	76.66666667	52.33333333	76.66666667	60	60	63.33333333	41.33333333	63.33333333
PVA4	52.33333333	76.66666667	70	60	70	76.66666667	53.33333333	73.33333333
	PVC9	PVC10	PVC11	PVC12	PVC13	PVC14	PVC15	PVC16
PVA1	53.33333333	35.66666667	63.33333333	76.66666667	53.33333333	73.33333333	73.33333333	56.66666667
PVA2	35.66666667	63.33333333	56.66666667	43.33333333	56.66666667	52.33333333	56.66666667	76.66666667
PVA3	42.33333333	83.33333333	43.33333333	66.66666667	76.66666667	45.66666667	63.33333333	70
PVA4	76.66666667	73.33333333	42.33333333	73.33333333	66.66666667	46.66666667	52.33333333	28

The weights of the criteria are computed by the normalization values in figure 3.

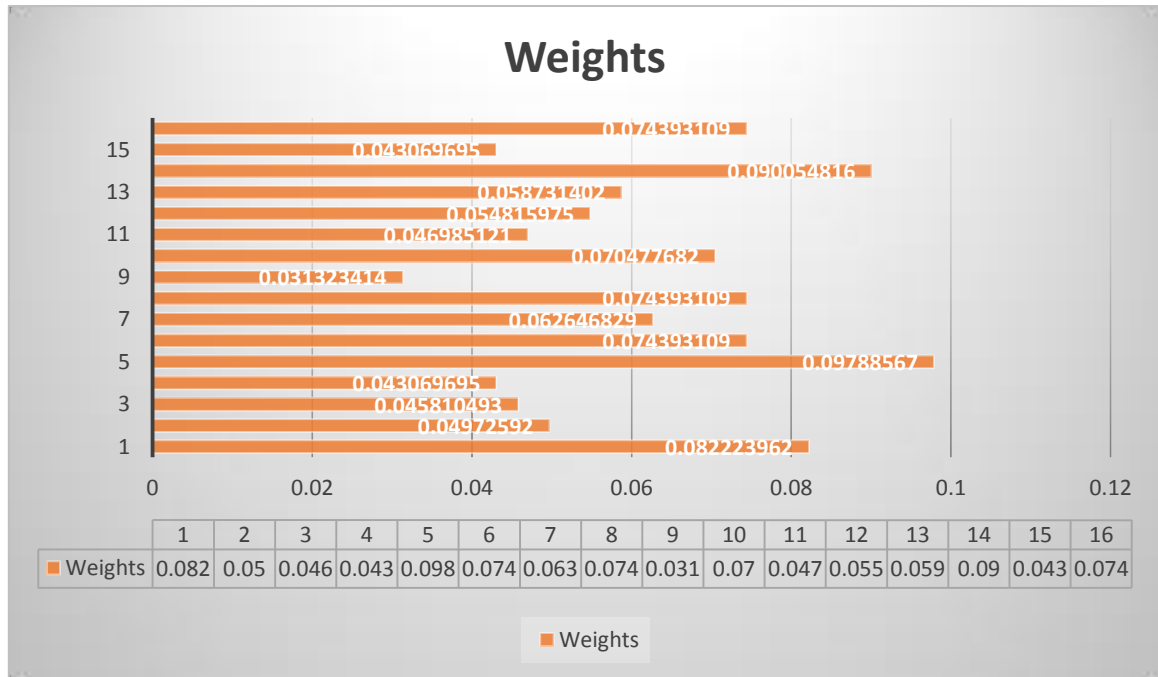


Figure 4: The weights of criteria.

According to Eq. (2,3), the normalization matrix is computed in table 3.

Table 3: The normalization values of the candidate.

	PVC1	PVC2	PVC3	PVC4	PVC5	PVC6	PVC7	PVC8
PVA1	1	0.695652174	0.682608696	0.777777778	0.904761905	0.782608696	1	0.863636364
PVA2	1	0.769565217	0.608695652	0.983333333	1	0.869565217	0.714285714	0.713636364
PVA3	1	0.682608696	1	1	0.857142857	0.826086957	0.59047619	0.863636364
PVA4	0.682608696	1	0.913043478	1	1	1	0.761904762	1
	PVC9	PVC10	PVC11	PVC12	PVC13	PVC14	PVC15	PVC16
PVA1	0.695652174	0.428	1	1	0.695652174	0.622727273	0.713636364	0.494117647
PVA2	0.465217391	0.76	0.894736842	0.565217391	0.739130435	0.872611465	0.923529412	0.365217391
PVA3	0.552173913	1	0.684210526	0.869565217	1	1	0.826315789	0.4
PVA4	1	0.88	0.668421053	0.956521739	0.869565217	0.978571429	1	1

Eqs. (6,7) are used to compute the normalization of standard deviation and degree of conflict in tables 4,5.

Table 4: The normalization values of standard deviation.

	PVC1	PVC2	PVC3	PVC4	PVC5	PVC6	PVC7	PVC8
PVA1	0.082223962	0.000149574	0.000101792	0.000772432	0.019736403	0.001473152	0.062646829	0.007125698
PVA2	0.082223962	0.000752506	1.62693E-05	0.032914251	0.09788567	0.007950002	0.000287641	0.000336639
PVA3	0.082223962	0.000110492	0.045810493	0.043069695	0.008309416	0.003499008	1.36816E-05	0.007125698
PVA4	0.000182704	0.04972592	0.010686323	0.043069695	0.09788567	0.074393109	0.000807812	0.074393109
	PVC9	PVC10	PVC11	PVC12	PVC13	PVC14	PVC15	PVC16
PVA1	9.42201E-05	8.93618E-08	0.046985121	0.054815975	0.000176663	4.60546E-05	0.000194896	9.39331E-07
PVA2	1.50787E-07	0.00087311	0.007926573	5.94779E-06	0.000466023	0.010177511	0.012061005	7.45343E-09
PVA3	2.33929E-06	0.070477682	0.000108392	0.005857897	0.058731402	0.090054816	0.002034739	3.19516E-08
PVA4	0.031323414	0.009115371	7.4604E-05	0.026916876	0.006276318	0.063677711	0.043069695	0.074393109

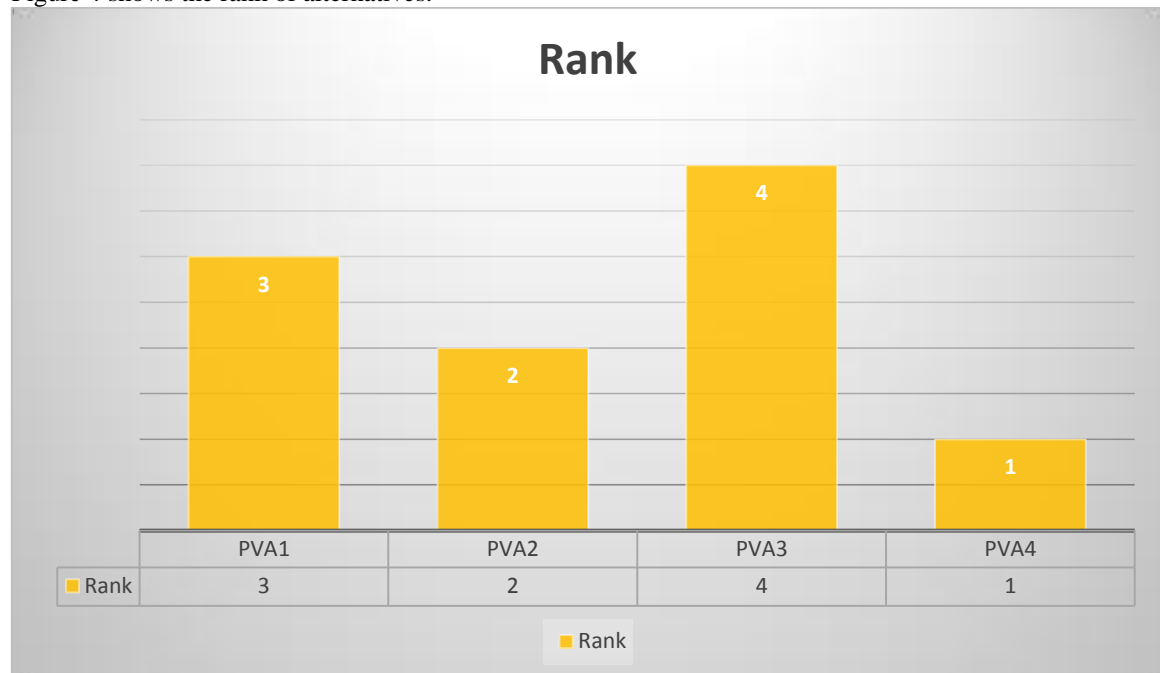
Table 5: The normalization values of degree of conflict.

	PVC1	PVC2	PVC3	PVC4	PVC5	PVC6	PVC7	PVC8
PVA1	0.508768897	0.881591362	1.335321435	1.108516679	3.232242563	0.614207657	1.1360447	10.94796633
PVA2	0.508768897	0.975260444	1.19073249	1.401481801	3.572478623	0.682452952	0.8114605	9.046477439
PVA3	0.508768897	0.865061524	1.956203376	1.42523573	3.062124534	0.648330304	0.670807347	10.94796633

PVA4	0.347290073	1.267287583	1.786098734	1.42523573	3.572478623	0.784820895	0.865557867	12.67659259
	PVC9	PVC10	PVC11	PVC12	PVC13	PVC14	PVC15	PVC16
PVA1	0.706136357	0.223020575	0.878933784	1.195648228	4.131046771	2.341548633	1.718052444	1.18956947
PVA2	0.472228689	0.396017843	0.786414439	0.675801173	4.389237194	3.28115095	2.223361986	0.879247
PVA3	0.560495733	0.521076109	0.601375747	1.039694112	5.938379733	3.760151089	1.989323883	0.962984809
PVA4	1.015071013	0.458546976	0.587497845	1.143663523	5.163808463	3.679576423	2.407462023	2.407462023

The values of A_b, R_c are computed by using Eqs. (14,15).

Then rank the alternatives. The best alternative is PVA₃ followed by PVA₁ then PVA₂, then PVA₄. Figure 4 shows the rank of alternatives.



Figures 5: The rank of alternatives.

Now imagine that country constructs a PV power plant on an island to provide energy to ships. Each of the four specialists is asked to join a committee. The process then employs the satellite map, the traffic map, and the grid map to arrive at four potential solutions, after which field research is conducted.

Six quantitative criteria and nine qualitative factors make up the assessment criteria system proposed in this research. The committee evaluated the qualitative responses. Initial steps include collecting the bare essentials of four potential solutions.

Second, the information gathered is used by the committee's changeable number of members to weigh the options.

5. Conclusion

The IPVCS location selection decision is an MCDM problem because of the connection among different factors inhibiting the site. An assessment system based on this structure has been constructed, and two new assessments have been proposed, one of which is 'Probability of Extreme Weather' and the other is the distance of the ship from the IPVCS site. It is possible to deal with the correlation between criteria in this paper and to take into account the difference between the best and worst alternatives so that the decision is more comprehensive and accurate.

Expert ratings have an element of uncertainty about them. An inexperienced decision-maker is unable to provide an accurate value because the decision-making landscape is difficult to comprehend.

Only a portion of the ship's electrical power needs can be met by the site selection results presented in this paper. For powered ships, a percentage of IPVCS can be chosen from the following list. An electric ship can travel overseas because it provides charging service at various points during the ship's operation.

IPVCS is assumed to have the same scale in this article. This is completely out of line. In the future, different-sized charging stations should be built per the power requirements of ships, so that PV power can be fully utilized and IPVCS is more affordable. In addition, the power storage system's ability should be taken into account to grow the economy. In addition to IPVCS, research into the charging point capacity and the amount of charging piles can also be taken into account, as can the charging path improvement of electric ships.

References

- [1] R. Dang, X. Li, C. Li, and C. Xu, "A MCDM framework for site selection of island photovoltaic charging station based on new criteria identification and a hybrid fuzzy approach," *Sustainable Cities and Society*, vol. 74, p. 103230, 2021.
- [2] C. Yongdao, "Current status and development trend of ship power system [J]," *Machinery Manufacturing and Automation*, vol. 42, no. 02, pp. 164–166, 2013.
- [3] N. M. Silvério, R. M. Barros, G. L. Tiago Filho, M. Redón-Santafé, I. F. S. dos Santos, and V. E. de Mello Valerio, "Use of floating PV plants for coordinated operation with hydropower plants: Case study of the hydroelectric plants of the São Francisco River basin," *Energy Conversion and Management*, vol. 171, pp. 339–349, 2018.
- [4] H. Khaloie *et al.*, "Coordinated wind-thermal-energy storage offering strategy in energy and spinning reserve markets using a multi-stage model," *Applied Energy*, vol. 259, p. 114168, 2020.
- [5] H. Khaloie, A. Abdollahi, M. Rashidinejad, and P. Siano, "Risk-based probabilistic-possibilistic self-scheduling considering high-impact low-probability events uncertainty," *International Journal of Electrical Power & Energy Systems*, vol. 110, pp. 598–612, 2019.
- [6] H. Khaloie, A. Anvari-Moghaddam, N. Hatziaargyriou, and J. Contreras, "Risk-constrained self-scheduling of a hybrid power plant considering interval-based intraday demand response exchange market prices," *Journal of Cleaner Production*, vol. 282, p. 125344, 2021.
- [7] K. Trapani and D. L. Millar, "Proposing offshore photovoltaic (PV) technology to the energy mix of the Maltese islands," *Energy Conversion and Management*, vol. 67, pp. 18–26, 2013.
- [8] K. Trapani, D. L. Millar, and H. C. M. Smith, "Novel offshore application of photovoltaics in comparison to conventional marine renewable energy technologies," *Renewable energy*, vol. 50, pp. 879–888, 2013.
- [9] Y. Wu, L. Li, Z. Song, and X. Lin, "Risk assessment on offshore photovoltaic power generation projects in China based on a fuzzy analysis framework," *Journal of Cleaner Production*, vol. 215, pp. 46–62, 2019.
- [10] M. Dörenkämper, A. Wahed, A. Kumar, M. de Jong, J. Kroon, and T. Reindl, "The cooling effect of floating PV in two different climate zones: A comparison of field test data from the Netherlands and Singapore," *Solar Energy*, vol. 219, pp. 15–23, 2021.
- [11] G. Singh, P. Baredar, A. Singh, and D. Kurup, "Optimal sizing and location of PV, wind and battery storage for electrification to an island: A case study of Kavaratti, Lakshadweep," *Journal of Energy Storage*, vol. 12, pp. 78–86, 2017.
- [12] A. Aljanad, A. Mohamed, H. Shareef, and T. Khatib, "A novel method for optimal placement of vehicle-to-grid charging stations in distribution power system using a quantum binary lightning search algorithm," *Sustainable Cities and Society*, vol. 38, pp. 174–183, 2018.
- [13] L. Gong, W. Cao, K. Liu, and J. Zhao, "Optimal charging strategy for electric vehicles in residential charging station under dynamic spike pricing policy," *Sustainable Cities and Society*, vol. 63, p. 102474, 2020.
- [14] C. Zhang and P. Chen, "Economic benefit analysis of battery charging and swapping station for pure electric bus based on differential power purchase policy: a new power trading model," *Sustainable Cities and Society*, vol. 64, p. 102570, 2021.
- [15] S. Ozdemir and G. Sahin, "Multi-criteria decision-making in the location selection for a solar PV power plant using AHP," *Measurement*, vol. 129, pp. 218–226, 2018.
- [16] G. F. Nemet, "Beyond the learning curve: factors influencing cost reductions in photovoltaics," *Energy*

- policy, vol. 34, no. 17, pp. 3218–3232, 2006.
- [17] M. A. Jenifer and M. K. Jha, “Comparison of analytic hierarchy process, catastrophe and entropy techniques for evaluating groundwater prospect of hard-rock aquifer systems,” *Journal of Hydrology*, vol. 548, pp. 605–624, 2017.
- [18] X. Chuansheng, D. Dapeng, H. Shengping, X. Xin, and C. Yingjie, “Safety evaluation of smart grid based on AHP-entropy method,” *Systems Engineering Procedia*, vol. 4, pp. 203–209, 2012.
- [19] Y. Wu *et al.*, “Location selection of seawater pumped hydro storage station in China based on multi-attribute decision making,” *Renewable energy*, vol. 139, pp. 410–425, 2019.
- [20] F. Ma, J. He, J. Ma, and S. Xia, “Evaluation of urban green transportation planning based on central point triangle whiten weight function and entropy-AHP,” *Transportation Research Procedia*, vol. 25, pp. 3634–3644, 2017.
- [21] M. Uyan, “GIS-based solar farms site selection using analytic hierarchy process (AHP) in Karapinar region, Konya/Turkey,” *Renewable and Sustainable Energy Reviews*, vol. 28, pp. 11–17, 2013.
- [22] S. C. Rana and J. N. Patel, “Selection of best location for small hydro power project using AHP, WPM and TOPSIS methods,” *ISH Journal of Hydraulic Engineering*, vol. 26, no. 2, pp. 173–178, 2020.
- [23] D. Jun, F. Tian-Tian, Y. Yi-Sheng, and M. Yu, “Macro-site selection of wind/solar hybrid power station based on ELECTRE-II,” *Renewable and Sustainable Energy Reviews*, vol. 35, pp. 194–204, 2014.
- [24] W. Yun-na, Y. Yi-sheng, F. Tian-tian, K. Li-na, L. Wei, and F. Luo-jie, “Macro-site selection of wind/solar hybrid power station based on Ideal Matter-Element Model,” *International Journal of Electrical Power & Energy Systems*, vol. 50, pp. 76–84, 2013.
- [25] Y. Wu, B. Zhang, C. Xu, and L. Li, “Site selection decision framework using fuzzy ANP-VIKOR for large commercial rooftop PV system based on sustainability perspective,” *Sustainable cities and society*, vol. 40, pp. 454–470, 2018.
- [26] A. Stamatakis, M. Mandalaki, and T. Tsoutsos, “Multi-criteria analysis for PV integrated in shading devices for Mediterranean region,” *Energy and Buildings*, vol. 117, pp. 128–137, 2016.
- [27] Y. Wu *et al.*, “Optimal location selection for offshore wind-PV-seawater pumped storage power plant using a hybrid MCDM approach: a two-stage framework,” *Energy Conversion and Management*, vol. 199, p. 112066, 2019.
- [28] S. Opricovic and G.-H. Tzeng, “Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS,” *European journal of operational research*, vol. 156, no. 2, pp. 445–455, 2004.
- [29] M. Keshavarz-Ghorabae, M. Amiri, E. K. Zavadskas, Z. Turskis, and J. Antucheviciene, “Simultaneous evaluation of criteria and alternatives (SECA) for multi-criteria decision-making,” *Informatica*, vol. 29, no. 2, pp. 265–280, 2018.