energies

MDPI

Article

Solar Energy Deployment for the Sustainable Future of Vietnam: Hybrid SWOC-FAHP-WASPAS Analysis

Nguyen Van Thanh [1,*] and Nguyen Thi Kim Lan [2]

[1] Faculty of Commerce, Van Lang University, Ho Chi Minh City 70000, Vietnam
[2] International Education Institute, Van Lang University, Ho Chi Minh City 70000, Vietnam; lan.ntk@vlu.edu.vn
* Correspondence: thanh.nguyenvan@vlu.edu.vn

Abstract: In recent years, solar power has developed significantly in Vietnam, making an important contribution to ensuring energy conservation and decreasing greenhouse gas exposure. Recently, Vietnam has experienced impressive growth in the solar and wind energy sectors, showing the high potential of using renewable electricity in addressing energy needs. The target of this study was to construct a fuzzy multicriteria decision-making, model including strengths-weaknesses-opportunities-challenges (SWOC) analysis, the fuzzy analytic hierarchy process (F-AHP) model, and the weighted aggregates sum product assessment (WASPAS) model, to select the location of a solar power plant in south Vietnam. The proposed fuzzy multicriteria decision-making model (MCDM) model is the first solar power plant location selection in southern Vietnam that utilizes literature reviews and expert interviews. Moreover, this is the first study to provide a case study on evaluating locations during solar power plant location selection that utilizes a combination of the SWOC, FAHP, and WASPAS models. The findings of this study provide valuable knowledge for the assessment and selection of suitable locations for renewable energy projects, including both solar power energy projects and other renewable energy projects.

Keywords: fuzzy theory; MCDM model; solar energy; SFAHP; WASPAS

Citation: Thanh, N.V.; Lan, N.T.K. Solar Energy Deployment for the Sustainable Future of Vietnam: Hybrid SWOC-FAHP-WASPAS Analysis. *Energies* **2022**, *15*, 2798. https://doi.org/10.3390/en15082798

Academic Editors: Ling Ji, Yulei Xie and Zaoli Yang

Received: 8 March 2022
Accepted: 8 April 2022
Published: 11 April 2022

1. Introduction

Mekong Delta, Vietnam is facing significant increases in the demand for electricity because the demand for electricity for economic development is increasingly more rapidly than the economic growth rate. Considering the problems of identifying appropriate electricity sources for the development of the country and the pressure to manage the environment, the Mekong Delta has recently placed environment-friendly power plants in continuous operation, typically solar power [1].

Located in the monsoon tropics, with the potential for massive solar energy, the Mekong Delta is entering a changing era of solar energy growth and utilization. Solar power plants and projects in the Mekong Delta are mostly concentrated in hot, dry, and high areas along the southwestern border, between Vietnam and Cambodia. This area has a stable climate and weather, and the number of hours of sunshine is much higher than in the wider region [1].

With the advantage of a region with mild weather and climate, a stable rainy season, and an average number of sunny hours a year of over 2600, the average daily solar radiation intensity in the north is nearly 6 kWh/m^2. Along with large-scale factory construction projects, various applications of technology to utilize solar energy to generate electricity have been encouraged and widely disseminated by the authorities for use in daily life and production throughout the provinces in the Mekong Delta region [2,3]. Map of the annual average daily global horizontal irradiation is shown in Figure 1.

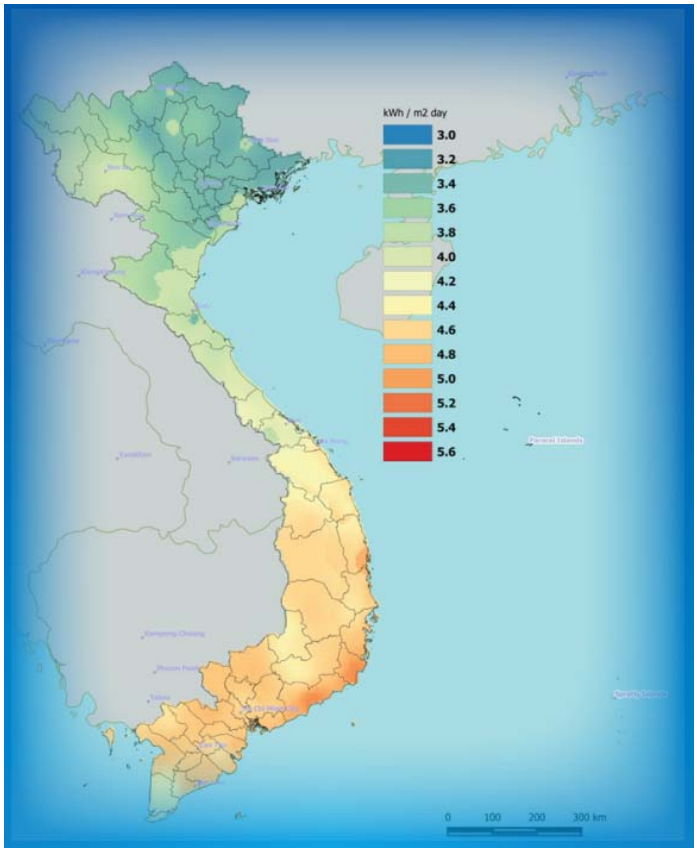

Figure 1. Map of the annual average daily global horizontal irradiation.

The selection of locations for solar power plants that are sustainable and satisfy the strengths-weaknesses-opportunities-challenges (SWOC) analysis concepts is vital for the development of the country's energy supply and to reduce environmental harm. Therefore, decision makers must consider both quantitative and qualitative factors.

In this study, two key processes were used to measure the performance level of each potential location. The weight of each criterion was initially computed by the fuzzy analytic hierarchy process (FAHP) approach. The relationships between the characteristics were explored in this manner to offer more realistic weights. The weighted aggregates sum product assessment (WASPAS) approach was deployed to determine the performance of each potential location in terms of the strengths-weaknesses-opportunities-challenges (SWOC) model.

An overview of the research contents and research goals is presented in the introduction section, and the basis for the formation of the research method is presented in the literature review section. The FAHP and WASPAS methods and case studies are introduced in Sections 3 and 4 of this article, respectively. The results and findings of this study are described in detail in the conclusion.

2. Literature Review

Researchers consider MCDM to be one of the most popular treaties in the literature. The term "MCDM" refers to the process of selecting the best option from a set of options. Many models have been used to show the decision-making procedure, some of which have used MCDM methods, which have been used separately or in combination with other MCDM methods and other strategies. Various studies have used MCDM models to solve complicated decision-making problems that involve multiple criteria. These models have been applied in various fields and sectors. In the field of supply chain management, MCDM models are regularly applied to solve problems, such as facility location selection [4–8], supplier performance evaluation [9–12], distribution channel development [13–15], etc. Among

these, supplier evaluation and selection processes, which involve multiple qualitative and quantitative criteria, are frequently supported by MCDM models.

Juan M.Sánchez-Lozano et al. [16] combined geographical information systems (GISs) and multi-criteria decision-making (MCDM) methods to assess the optimal photovoltaic solar power plant locations in southeast Spain. Devika Kannan et al. [17] introduced a hybrid model utilizing Monte Carlo simulation with MCDM procedures to choose solar power plant locations in east Iran.

Yeliz Simsek et al. [18] proposed a study that provides decision makers with a method for evaluating the sustainability of clean growth energy projects. Mehdi Jahangiri et al. [19] applied the fuzzy MCDM technique to determine the optimal location in Qatar for solar and wind energy plants to produce hydrogen and electricity power. Aleksandra Bączkiewicz et al. [20] present an approachable study based on two recently discovered multi-criteria decision-making (MCDM) methods: the characteristic objects method (COMET) combined with technique for order performance by similarity to ideal solution (TOPSIS) and stable preference ordering towards ideal solution (SPOTIS), which works as the baseline of a decision support system (DSS).

Chao-Rong Chen et al. [21] used a hybrid MCDM model, including decision-making trial and evaluation laboratory (DEMATEL) and DEMATEL-based analytic network process (DANP) based on geographical information systems (GISs), to improve the performance of solar farms. Pilar Díaz-Cuevas et al. [22] developed an integrated methodology using multi-criteria decision-making methods and geographical information systems to construct a renewable energy spatial planning model. Chia-Nan Wang et al. [23] used data envelopment analysis (DEA) and grey-based multiple criteria decision-making (G-MCDM) for site selection for solar energy. Murugaperumal Krishnamoorthy et al. [24] used two concepts to determine answers to questions related to micro-grid systems. As a result, the economic factor includes the total net present cost, and the cost of energy was found to be the lowest.

From this literature review, MCDM is the optimal technique for applications in complex situations that include multiple criteria and conflicting goals. This tool has received attention attention in the renewable energy industry because of its flexibility for decision-makers in multiple problems, such as project and location selection. Thus, in this study, we propose a fuzzy MCDM model for solar plant location selection.

3. Methodology

3.1. Fuzzy Analytic Hierarchy Process

The fuzzy AHP model implementation is divided into four steps, which are as follows [25–30]:

Step 1: Constructing the fuzzy AHP model.
Step 2: Constructing the pairwise comparison matrix.

Using fuzzy numbers, a pairwise comparison matrix is produced. The matrix is as follows:

$$\widetilde{A^k} = \begin{bmatrix} \widetilde{a_{11}^k} & \widetilde{a_{12}^k} & \cdots & \widetilde{a_{1n}^k} \\ \widetilde{a_{21}^k} & \widetilde{a_{22}^k} & \cdots & \widetilde{a_{2n}^k} \\ \cdots & \cdots & \cdots & \cdots \\ \widetilde{a_{n1}^k} & \widetilde{a_{n2}^k} & \cdots & \widetilde{a_{nn}^k} \end{bmatrix} \quad (1)$$

where:

$\widetilde{A^k}$ is the fuzzy element pairwise comparison matrix.

$\widetilde{a_{nn}^k}$ is the triangular fuzzy mean value when comparing the pair of priority between the items.

To convert fuzzy numbers to real numbers, the triangular fuzzy trigonometric technique is used as follows [31]:

$$t_{\alpha,\beta}(\overline{\alpha}_{ij}) = [\beta \cdot f_\alpha(L_{ij}) + (1-\beta) \cdot f_\alpha(U_{ij})] \quad (2)$$

With: $0 \leq \beta \leq 1,\ 0 \leq \alpha \leq 1$

where:

$$f_\alpha(L_{ij}) = (M_{ij} - L_{ij}) + L_{ij} \tag{3}$$

$$f_\alpha(U_{ij}) = U_{ij} - (U_{ij} - M_{ij}).\ \alpha \tag{4}$$

When the diagonal matrix is matched, we obtain:

$$t_{\alpha,\beta}(\overline{\alpha}_{ij}) = \frac{1}{t_{\alpha,\beta}(\overline{\alpha}_{ij})} \tag{5}$$

With: $0 \leq \beta \leq 1,\ 0 \leq \alpha \leq 1, i > j$.

We obtain a comparison matrix with the elements as real numbers after performing the conversion method to obtain the fuzzy comparison matrix. This matrix is made up of n lines and n columns (n is the number of indicators). The matrix's components represent the relative relevance of the indicator I vs. the column criteria:

$$A = (m_{ij})_{n \times n} = \begin{bmatrix} 1 & m_{12} & \dots & m_{1n} \\ m_{21} & 1 & \dots & m_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ m_{n1} & m_{n2} & \dots & 1 \end{bmatrix} \tag{6}$$

The scale fuzzy conversion scale established by Kuswandati [32] is used to evaluate the priority in the FAHP model.

Step 3: Determine the highest possible individual value.

The Lambda Max technique, developed by Saaty [33], is used to compute the maximum particular value of the indicator:

$$|A - \lambda_{\max}.I| = 0 \tag{7}$$

where:

$\lambda_{\max}$ as the matrix's maximum value.

A as the matrix of pairwise comparisons.

I is the same level unit matrix as matrix A.

Step 4: Check for consistency.

Saaty utilized the consistency ratio (CR) after computing the maximum individual value of the consistency index (CI). This ratio balances the degree of consistency with the data's (random) objectivity:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{8}$$

where CI represents the CI and RI represents the random index.

If CR ≤ 0.1, the fuzzy AHP model is adequate; otherwise, the pairwise comparison matrix must be re-evaluated:

$$\mathrm{CI} = \frac{\lambda_{\max} - \mathrm{n}}{\mathrm{n} - 1} \tag{9}$$

where:

$\lambda_{\max}$ is the matrix's maximum value

n is the proportion to the number of indicators.

Saaty examined the production of random matrices for each n-level comparison matrix and determined the RI according to the number of indications.

3.2. The Weighted Aggregates Sum Product Assessment (WASPAS)

When faced with a decision-making challenge, MCDM approaches, such as the weighted product model (WPM) and the weighted sum model (WSM), are commonly used to determine the optimal choice. WASPAS, a mixture of the aforementioned methods,

is one of the most recent methods that can improve the accuracy in selecting the best alternative [34]. According to the study, the WASPAS approach is more accurate than the WPM and WSM methods.

In recent years, the WASPAS approach has been used in a variety of applications. Bagocius et al. [35] examined the WASPAS approach in conjunction with entropy methods in order to establish an ideal site for a deep-water port in Europe. Turkis et al. [36] used a combination technique of fuzzy WASPAS and fuzzy AHP to identify a site for a retail center location owing to the intricacy of the problem. As a result of the preceding investigations, the WASPAS approach and its accuracy are employed for this study of risk qualitative analysis (RQA), as indicated below [36]:

1. $X = \left[x_{ij}\right]_{q\times r}$ is used to create a decision matrix, where x_{ij} is the performance of the ith option with regard to the jth criterion, q denotes the number of alternatives, and r denotes the number of criteria.
2. The following two equations are used to normalize the decision matrix:

   Criteria for maximizing:
   $$\overline{X}_{ij} = \frac{x_{ij}}{max_i x_{ij}} \tag{10}$$

   Criteria for minimizing:
   $$\overline{X}_{ij} = \frac{min_i x_{ij}}{x_{ij}} \tag{11}$$
3. The following equation is used to determine the significance of the ith alternative:
   $$Q_i^{(1)} = \sum_{j=1}^{n} \overline{X}_{ij} W_j \tag{12}$$

   where W_j represents the weight (relative significance) of the jth criteria.
4. The overall significance of the ith choice is then determined using the following equation:
   $$Q_i^{(2)} = \prod_{j=1}^{n} \left(\overline{X}_{ij}\right)^{w_j} \tag{13}$$
5. The two WSM and WPM approaches are then blended using the joint additive based on the following equation:
   $$Q_i = 0.5Q_i^{(1)} + 0.5Q_i^{(2)} \tag{14}$$
6. The following equation defines a more generalized equation for estimating the importance using the WASPAS method:
   $$Q_i = \lambda \sum_{j=1}^{n} \overline{X}_{ij} W_j + (1-\lambda) \prod_{j=1}^{n} \left(\overline{X}_{ij}\right)^{w_j},\ \lambda = 0, \ldots, 1 \tag{15}$$
7. The following equation is used to obtain the optimum values:
   $$\lambda = \frac{\sigma^2\left(Q_i^{(2)}\right)}{\sigma^2\left(Q_i^{(1)}\right) + \sigma^2\left(Q_i^{(2)}\right)} \tag{16}$$

   The variances $\sigma^2\left(Q_i^{(1)}\right)$ and $\sigma^2\left(Q_i^{(2)}\right)$ are calculated by the following equations:
   $$\sigma^2\left(Q_i^{(1)}\right) = \sum_{j=1}^{n} W_j^2 \sigma^2\left(\overline{X}_{ij}\right) \overline{X}_{ij} \tag{17}$$

$$\sigma^2\left(Q_i^{(1)}\right) = \sum_{j=1}^{n}\left(\frac{\prod_{j=1}^{n}\left(\overline{X}_{ij}\right)^{wj} w_j}{\left(\overline{X}_{ij}\right)^{wj}\left(\overline{X}_{ij}\right)^{(1-w_j)}}\right)^2 \sigma^2\left(\overline{X}_{ij}\right) \quad (18)$$

8. The normalized variance estimates for the first criterion values are derived as follows:

$$\sigma^2\left(\overline{X}_{ij}\right) = \left(0.05\overline{X}_{ij}\right)^2 \quad (19)$$

4. Case Study

With a lot of potential for renewable energy development, the Mekong Delta region is witnessing strong development of renewable power sources, especially wind and solar energy [37].

In this study, an F-MCDM model was utilized, including strengths-weaknesses-opportunities-challenges (SWOC) analysis, the fuzzy analytic hierarchy process (F-AHP) model, and the weighted aggregates sum product assessment (WASPAS) model, for plant location selection to provide solar energy in the south of Vietnam. In the initial stage of this study, all criteria were defined using SWOC analysis, experts, and a literature review. The fuzzy AHP structure of this study is shown in Figure 2.

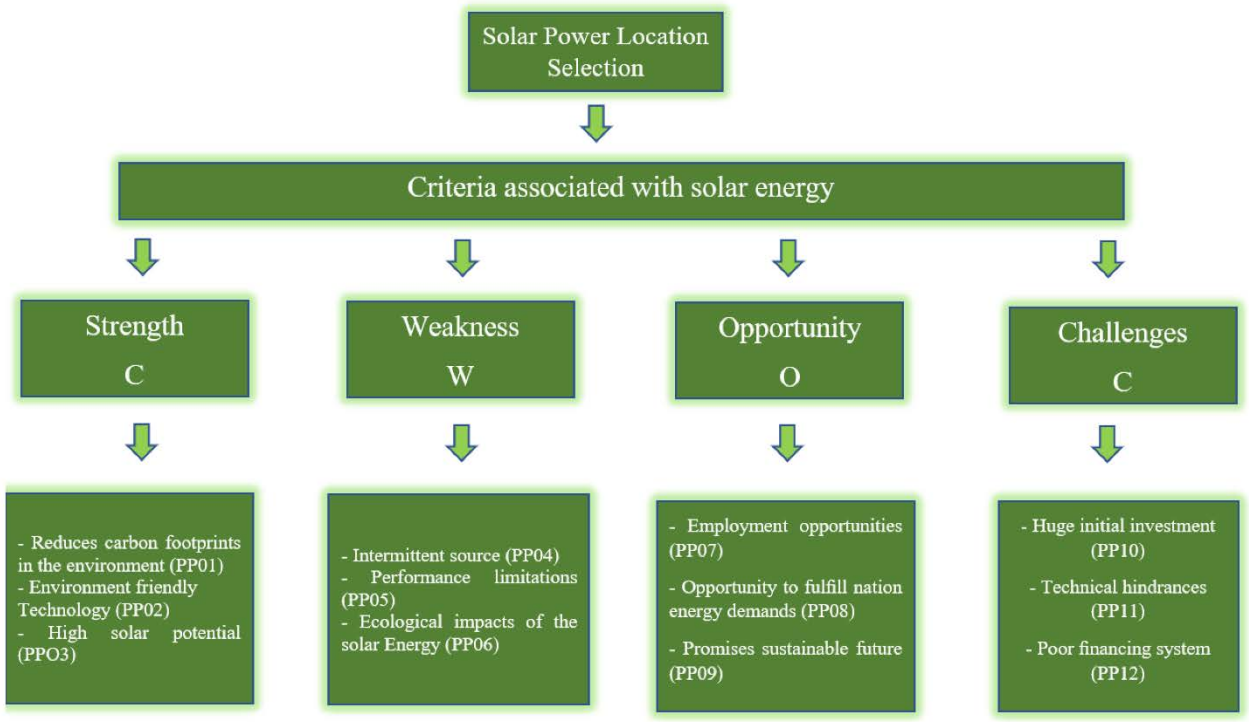

Figure 2. Fuzzy AHP structure of the study.

The Mekong Delta has a monsoon climate with two seasons: hot and rainy seasons. Every year, the region receives an average of 2200–2500 sunshine hours, with an average daily solar radiation energy of 4.3–4.9 kWh/m^2. This clearly indicates the potential for light energy conversion. It is estimated that for every 1m^2 of solar panels, 5 kWh can be converted each day. This light source is very consistent, with more than 90% of the days of each year receiving an adequate amount of sunlight for the solar panels to maintain operations [38]. According to experts, there are eight locations (SP) with many favorable conditions for the development of solar energy. Information about these locations is presented in Figure 3 and Table 1.

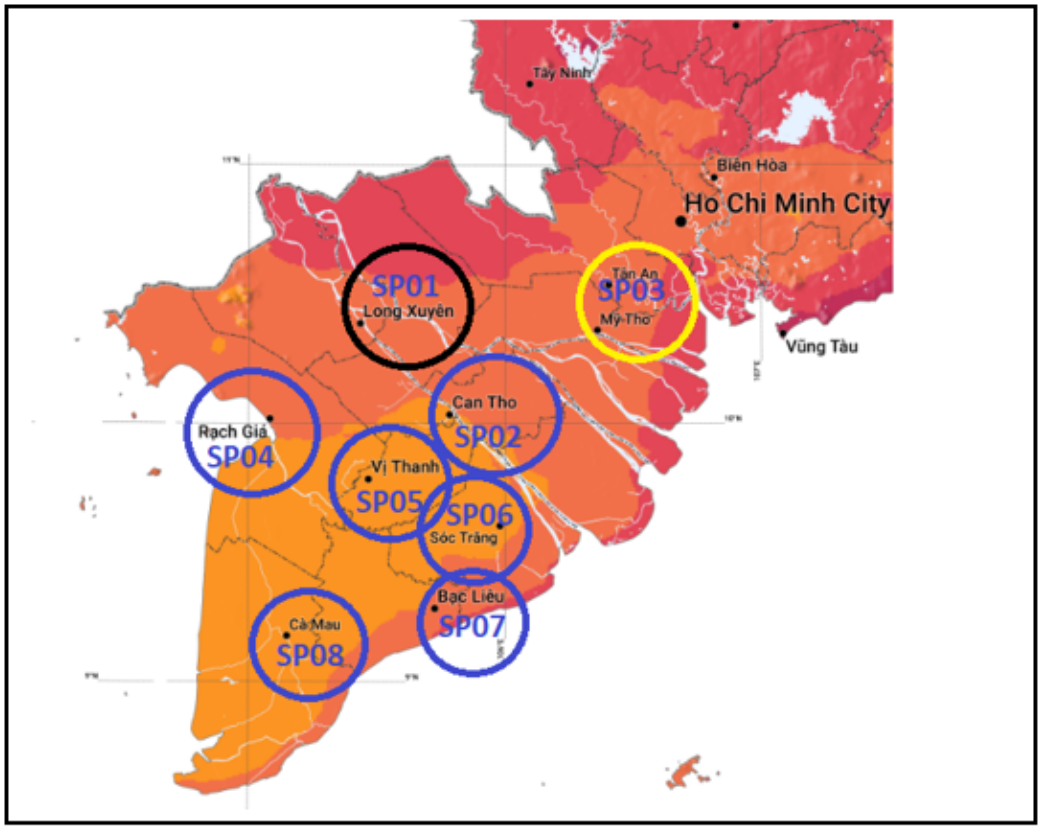

Figure 3. Potential locations in Mekong Delta, Vietnam for solar power plant setup.

Table 1. Eight potential locations for solar power plant investment.

No.	Name	Symbol
1	Long Xuyen, An Giang	SP01
2	Can Tho	SP02
3	My Tho, Tien Giang	SP03
4	Rach Gia, Kien Giang	SP04
5	Vi Thanh, Hau Giang	SP05
6	Soc Trang	SP06
7	Bac Lieu	SP07
8	Ca Mau	SP08

In the multi-criteria decision-making model, the weight of the criteria significantly affects the model's results. In this study, the FAHP model was applied to determine the weights of the criteria, all input data were evaluated by experts, and the result of the FAHP model was checked using the consistency ratio (CR) and consistency index (CI). The results are shown in Table 2.

In the final stage, the weighted aggregates sum product assessment (WASPAS) approach was employed to calculate the performance of each potential location in terms of the strengths-weaknesses-opportunities-challenges (SWOC) model. A result of WASPAS model is shown in Tables 3–6.

In this study, an MCDM-based approach was developed for the selection of locations for solar power plants in an uncertain decision-making environment. The selection criteria were ensured to satisfy the SWOC framework, where strengths, weaknesses, opportunities, and challenges criteria were considered. The proposed method employed FAHP to calculate the criteria weights and the WASPAS method to determine the performance score and ranking of potential locations in Mekong Delta Vietnam. As shown in Figure 4, SP01 (Long Xuyen, An Giang) is the optimal location in this study.

Table 2. The weight of all criteria.

Criteria	Fuzzy Sum of Each Row			Fuzzy Synthetic Extent			Degree of Possibility (Mi)	Normalization
PP01	7.71623	10.35757	13.91593	0.03624	0.06463	0.11708	0.50695	0.06053
PP02	12.57650	17.28859	23.04919	0.05906	0.10787	0.19393	0.93112	0.11118
PP03	13.33665	18.84530	24.78639	0.06263	0.11759	0.20854	1.00000	0.11941
PP04	10.21413	13.82293	18.11561	0.04797	0.08625	0.15242	0.74128	0.08851
PP05	13.59007	17.57221	22.04804	0.06382	0.10964	0.18550	0.93928	0.11216
PP06	7.16564	9.43127	12.91733	0.03365	0.05885	0.10868	0.43946	0.05247
PP07	7.85250	10.27848	13.71735	0.03688	0.06413	0.11541	0.49684	0.05933
PP08	9.63003	12.86083	16.87061	0.04522	0.08025	0.14194	0.67990	0.08118
PP09	10.20564	13.81943	18.50159	0.04793	0.08623	0.15566	0.74790	0.08930
PP10	8.39975	11.30355	15.47744	0.03945	0.07053	0.13022	0.58955	0.07040
PP11	8.04400	10.68611	14.53360	0.03778	0.06668	0.12228	0.53952	0.06442
PP12	10.12401	13.99897	19.01034	0.04754	0.08735	0.15995	0.76293	0.09110

Table 3. Normalized matrix.

	SP01	SP02	SP03	SP04	SP05	SP06	SP07	SP08
PP01	1.0000	0.9000	0.8000	0.7000	0.6000	0.9000	1.0000	0.6000
PP02	1.0000	0.9000	0.8000	0.8000	0.6000	0.7000	0.8000	0.9000
PP03	0.8889	0.7778	1.0000	0.8889	0.8889	1.0000	0.7778	0.6667
PP04	0.7000	0.9000	0.9000	0.8000	0.9000	0.8000	1.0000	0.9000
PP05	1.0000	0.7778	0.6667	1.0000	0.8889	1.0000	0.8889	1.0000
PP06	0.8889	0.7778	0.7778	0.8889	0.8889	1.0000	0.8889	0.8889
PP07	1.0000	0.6667	0.7778	0.7778	1.0000	1.0000	0.8889	1.0000
PP08	0.7778	0.8889	0.8889	1.0000	1.0000	0.8889	0.7778	1.0000
PP09	1.0000	0.7778	0.6667	0.8889	0.8889	0.8889	0.7778	1.0000
PP10	0.8889	0.6667	0.7778	0.8889	1.0000	0.7778	0.8889	0.7778
PP11	1.0000	0.6667	0.7778	0.6667	0.8889	0.7778	1.0000	0.8889
PP12	0.6667	0.7778	0.8889	1.0000	0.8889	0.7778	1.0000	1.0000

Table 4. Weighted normalized matrix.

	SP01	SP02	SP03	SP04	SP05	SP06	SP07	SP08
PP01	0.0605	0.0545	0.0484	0.0424	0.0363	0.0545	0.0605	0.0363
PP02	0.1112	0.1001	0.0889	0.0889	0.0667	0.0778	0.0889	0.1001
PP03	0.1061	0.0929	0.1194	0.1061	0.1061	0.1194	0.0929	0.0796
PP04	0.0620	0.0797	0.0797	0.0708	0.0797	0.0708	0.0885	0.0797
PP05	0.1122	0.0872	0.0748	0.1122	0.0997	0.1122	0.0997	0.1122
PP06	0.0466	0.0408	0.0408	0.0466	0.0466	0.0525	0.0466	0.0466
PP07	0.0593	0.0396	0.0461	0.0461	0.0593	0.0593	0.0527	0.0593
PP08	0.0631	0.0722	0.0722	0.0812	0.0812	0.0722	0.0631	0.0812
PP09	0.0893	0.0695	0.0595	0.0794	0.0794	0.0794	0.0695	0.0893
PP10	0.0626	0.0469	0.0548	0.0626	0.0704	0.0548	0.0626	0.0548
PP11	0.0644	0.0429	0.0501	0.0429	0.0573	0.0501	0.0644	0.0573
PP12	0.0607	0.0709	0.0810	0.0911	0.0810	0.0709	0.0911	0.0911

Table 5. Exponentially weighted matrix.

	SP01	SP02	SP03	SP04	SP05	SP06	SP07	SP08
PP01	1.0000	0.9936	0.9866	0.9786	0.9696	0.9936	1.0000	0.9696
PP02	1.0000	0.9884	0.9755	0.9755	0.9448	0.9611	0.9755	0.9884
PP03	0.9860	0.9704	1.0000	0.9860	0.9860	1.0000	0.9704	0.9527
PP04	0.9689	0.9907	0.9907	0.9804	0.9907	0.9804	1.0000	0.9907

Table 5. *Cont.*

	SP01	SP02	SP03	SP04	SP05	SP06	SP07	SP08
PP05	1.0000	0.9722	0.9555	1.0000	0.9869	1.0000	0.9869	1.0000
PP06	0.9938	0.9869	0.9869	0.9938	0.9938	1.0000	0.9938	0.9938
PP07	1.0000	0.9762	0.9852	0.9852	1.0000	1.0000	0.9930	1.0000
PP08	0.9798	0.9905	0.9905	1.0000	1.0000	0.9905	0.9798	1.0000
PP09	1.0000	0.9778	0.9644	0.9895	0.9895	0.9895	0.9778	1.0000
PP10	0.9917	0.9719	0.9825	0.9917	1.0000	0.9825	0.9917	0.9825
PP11	1.0000	0.9742	0.9839	0.9742	0.9924	0.9839	1.0000	0.9924
PP12	0.9637	0.9774	0.9893	1.0000	0.9893	0.9774	1.0000	1.0000

Table 6. Final ranking score.

Alternatives	Qi1	Qi2	Qi	Ranking
SP01	0.8981	0.8892	0.8937	1
SP02	0.7970	0.7926	0.7948	8
SP03	0.8157	0.8093	0.8125	7
SP04	0.8704	0.8640	0.8672	5
SP05	0.8637	0.8637	0.8637	6
SP06	0.8737	0.8737	0.8737	4
SP07	0.8806	0.8806	0.8806	3
SP08	0.8874	0.8874	0.8874	2

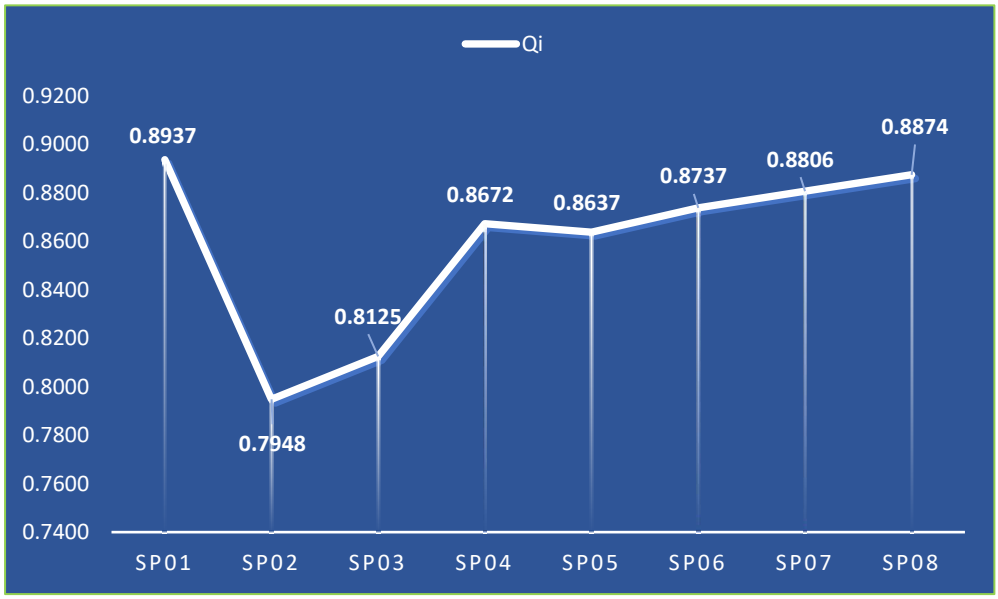

Figure 4. Ranking list from the WASPAS model.

5. Conclusions

The Mekong Delta is a very favorable place for the development of an energy industry cluster, especially solar energy, with an average radiation of 1387–1534 Kwh/KWp/year. The solar energy sector plays an important role in the development of the country's energy power and mitigation of environmental harms. In addition to the advantage of being one of the countries that experiences the most sunshine hours each year on the world solar radiation map, the government's preferential policies have created creating an impetus for solar power in Vietnam.

The MCDM model has been applied in many fields of engineering and science, but few works have used it for solar plant location selection under fuzzy environment conditions. In this study, two key processes were used to measure the performance level of each potential

location. The weight of each criterion was computed in the first stage using the fuzzy analytic hierarchy process (FAHP) approach. The relationships between the characteristics were explored in this manner to offer more realistic weights. The weighted aggregates sum product assessment (WASPAS) approach was employed to calculate the performance of each potential location in terms of the strengths-weaknesses-opportunities-challenges (SWOC) model. The findings suggest that Long Xuyen, An Giang (SP01) is the most suitable location with a ranking score of 0.8937. The significant findings are explained as follows:

- ✓ The first hybrid framework for location evaluation and selection in Vietnam that uses SWOC analysis.
- ✓ The first study with the assistance of a case study that utilizes SWOC analysis, FAHP, and WASPAS together.
- ✓ The results of this study serve as a suitable calculation method for evaluating and selecting optimal locations for solar power plants, for both solar energy projects in Mekong Delta and globally.

For future research, the proposed model can be combined with other decision-making support model, such as TOPSIS and DEA, to determine the optimal locations for renewable energy projects.

Author Contributions: Conceptualization, N.V.T. and N.T.K.L.; Data curation, N.V.T. and N.T.K.L.; Formal analysis, N.V.T. and N.T.K.L.; Funding acquisition, N.V.T.; Investigation, N.T.K.L.; Methodology, N.V.T. and N.T.K.L.; Project administration, N.V.T.; Resources, N.V.T. and N.T.K.L.; Supervision, N.V.T.; Validation, N.V.T.; Writing—original draft, N.V.T.; Writing—review and editing, N.T.K.L. All authors have read and agreed to the published version of the manuscript.

Funding: The authors wish to express their gratitude to Van Lang University, Vietnam for financial support for this research.

Acknowledgments: The authors wish to express their gratitude to Van Lang University, Vietnam for support for this research.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Điện Mặt Trời ở Đồng Bằng Sông Cửu Long Trên đà Phát Triển. Available online: https://kinhdoanhvaphattrien.vn/dien-mat-troi-o-dong-bang-song-cuu-long-tren-da-phat-trien.html (accessed on 10 August 2021).
2. Điện Mặt Trời Phát Triển Mạnh ở Đồng Bằng Sông Cửu Long. Available online: http://ceid.gov.vn/dien-mat-troi-phat-trien-manh-o-dong-bang-song-cuu-long/ (accessed on 10 August 2021).
3. Solar Resource Maps and GIS Data for 200+ Countries. Available online: https://solargis.com/maps-and-gis-data/overview (accessed on 10 August 2021).
4. Kieu, P.; Nguyen, V.; Nguyen, V.; Ho, T. A Spherical Fuzzy Analytic Hierarchy Process (SF-AHP) and Combined Compromise Solution (CoCoSo) Algorithm in Distribution Center Location Selection: A Case Study in Agricultural Supply Chain. *Axioms* **2021**, *10*, 53. [CrossRef]
5. Tadić, S.; Krstić, M.; Roso, V.; Brnjac, N. Dry port terminal location selection by applying the hybrid grey MCDM model. *Sustainability* **2020**, *12*, 6983. [CrossRef]
6. Budak, A.; Kaya, İ.; Karaşan, A.; Erdoğan, M. Real-time location systems selection by using a fuzzy MCDM approach: An application in humanitarian relief logistics. *Appl. Soft Comput.* **2020**, *92*, 106322. [CrossRef]
7. Wang, C.; Nguyen, V.; Thai, H.; Duong, D. Multi-criteria decision making (MCDM) approaches for solar power plant location selection in Viet Nam. *Energies* **2018**, *11*, 1504. [CrossRef]
8. Ulutaş, A.; Balo, F.; Sua, L.; Demir, E.; Topal, A.; Jakovljević, V. A new integrated grey MCDM model: Case of warehouse location selection. *Facta Univ. Ser. Mech. Eng.* **2021**, *19*, 515. [CrossRef]
9. Dweiri, F.; Kumar, S.; Khan, S.; Jain, V. Designing an integrated AHP based decision support system for supplier selection in automotive industry. *Expert Syst. Appl.* **2016**, *62*, 273–283. [CrossRef]
10. Wang, C.; Nguyen, V.; Kao, J.; Chen, C.; Nguyen, V. Multi-criteria decision-making methods in fuzzy decision problems: A case study in the frozen shrimp industry. *Symmetry* **2021**, *13*, 370. [CrossRef]
11. Rezaeisaray, M.; Ebrahimnejad, S.; Khalili-Damghani, K. A novel hybrid MCDM approach for outsourcing supplier selection. *J. Model. Manag.* **2016**, *11*, 536–559. [CrossRef]
12. Yazdani, M.; Chatterjee, P.; Zavadskas, E.; Zolfani, S.H. Integrated QFD-MCDM framework for green supplier selection. *J. Clean. Prod.* **2017**, *142*, 3728–3740. [CrossRef]

13. Liu, H.; Quan, M.; Li, Z.; Wang, Z. A new integrated MCDM model for sustainable supplier selection under interval-valued intuitionistic uncertain linguistic environment. *Inf. Sci.* **2019**, *486*, 254–270. [CrossRef]
14. Prabhuram, T.; Rajmohan, M.; Tan, Y.; Johnson, R.R. Performance evaluation of Omni channel distribution network configurations using multi criteria decision making techniques. *Ann. Oper. Res.* **2020**, *288*, 435–456. [CrossRef]
15. Titiyal, R.; Bhattacharya, S.; Thakkar, J. The distribution strategy selection for an e-tailer using a hybrid DANP VIKOR MCDM model. *Benchmark. Int. J.* **2019**, *26*, 395–433. [CrossRef]
16. Sánchez-Lozano, J.M.; Teruel-Solano, J.; Soto-Elvira, P.L.; García-Cascales, M.S. Geographical Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) methods for the evaluation of solar farms locations: Case study in south-eastern Spain. *Renew. Sustain. Energy Rev.* **2013**, *24*, 544–556. [CrossRef]
17. Kannan, D.; Moazzeni, S.; mostafayi Darmian, S.; Afrasiabi, A. A hybrid approach based on MCDM methods and Monte Carlo simulation for sustainable evaluation of potential solar sites in east of Iran. *J. Clean. Prod.* **2021**, *279*, 122368. [CrossRef]
18. Simsek, Y.; Watts, D.; Escobar, R. Sustainability evaluation of concentrated solar power (CSP) projects under clean development mechanism (CDM) by using multi criteria decision method (MCDM). *Renew. Sustain. Energy Rev.* **2018**, *93*, 421–438. [CrossRef]
19. Jahangiri, M.; Shamsabadi, A.A.; Mostafaeipour, A.; Rezaei, M.; Yousefi, Y.; Pomares, L.M. Using fuzzy MCDM technique to find the best location in Qatar for exploiting wind and solar energy to generate hydrogen and electricity. *Int. J. Hydrogen Energy* **2020**, *45*, 13862–13875. [CrossRef]
20. Bączkiewicz, A.; Kizielewicz, B.; Shekhovtsov, A.; Yelmikheiev, M.; Kozlov, V.; Sałabun, W. Comparative Analysis of Solar Panels with Determination of Local Significance Levels of Criteria Using the MCDM Methods Resistant to the Rank Reversal Phenomenon. *Energies* **2021**, *14*, 5727. [CrossRef]
21. Chen, C.R.; Huang, C.C.; Tsuei, H.J. A hybrid MCDM model for improving GIS-based solar farms site selection. *Int. J. Photoenergy* **2014**, *2014*, 925370. [CrossRef]
22. Díaz-Cuevas, P.; Domínguez-Bravo, J.; Prieto-Campos, A. Integrating MCDM and GIS for renewable energy spatial models: Assessing the individual and combined potential for wind, solar and biomass energy in Southern Spain. *Clean Technol. Environ. Policy* **2019**, *21*, 1855–1869. [CrossRef]
23. Wang, C.N.; Dang, T.T.; Wang, J.W. A combined Data Envelopment Analysis (DEA) and Grey Based Multiple Criteria Decision Making (G-MCDM) for solar PV power plants site selection: A case study in Vietnam. *Energy Rep.* **2022**, *8*, 1124–1142. [CrossRef]
24. Krishnamoorthy, M.; Periyanayagam AD, V.R.; Santhan Kumar, C.; Praveen Kumar, B.; Srinivasan, S.; Kathiravan, P. Optimal sizing, selection, and techno-economic analysis of battery storage for PV/BG-based hybrid rural electrification system. *IETE J. Res.* **2020**, 1–16. [CrossRef]
25. Lee, A.H.I. A fuzzy supplier selection model with the consideration of benefits opportunities, costs and risks. *Expert Syst. Appl.* **2009**, *36*, 2879–2893. [CrossRef]
26. Lee, H.I.; Kang, H.Y.; Hsu, C.F.; Hung, H.C. A green supplier selection model for high-tech industry. *Expert Syst. Appl.* **2009**, *36*, 7917–7927. [CrossRef]
27. Lee, H.I.; Kang, H.Y.; Hsu, C.F.; Hung, H.C. Fuzzy multiple goal programming applied to TFT-LCD supplier selection by downstream manufacturers. *Expert Syst. Appl.* **2009**, *36*, 6318–6325. [CrossRef]
28. Lee, H.I.; Kang, H.Y.; Wang, W.P. Analysis of priority mix planning for semiconductor fabrication under uncertainly. *Int. J. Adv. Manuf. Technol.* **2005**, *28*, 351–361. [CrossRef]
29. Cheng, C.H. Evaluating weapon systems using ranking fuzzy numbers. *Fuzzy Sets Syst.* **1999**, *107*, 25–35. [CrossRef]
30. dehghani, M.; Esmaeilian, M.; Tavakkoli-Moghaddam, R. Employing Fuzzy ANP for Green Supplier Selection and Order Allocations: A Case Study. *Int. J. Econ. Manag. Sci.* **2013**, *2*, 565–575.
31. Lin, R.; Lin, J.J.; Shu, C.J.; Diodes, T.; Chao, H.; Peter, J.C. Note on group consistency in analytic hierarchy process. *Eur. J. Oper. Res.* **2008**, *190*, 627–678. [CrossRef]
32. Kuswandari, R. Assessment of Different Methods for Measuring the Sustainability of Forest Management. Master's Thesis, International Institute for Geo-Information Science and Earth Observation Science, Enschede, The Netherlands, 2004.
33. Saaty, T.L. *The Analytic Hierarchy Process—Planning, Priority Setting, Resource Allocation*; McGraw-Hill: New York, NY, USA, 1980.
34. Zavadskas, E.; Turskis, Z.; Antucheviciene, J. Optimization of weighted aggregated sum product assessment. *Electron. Electr. Eng.* **2012**, *122*, 3–6. [CrossRef]
35. Bagočius, V.; Zavadskas, K.; Turskis, Z. Multi-criteria selection of a deep-water port in Klaipeda. *Procedia Eng.* **2013**, *57*, 144–148. [CrossRef]
36. Turskis, Z.; Zavadskas, E.; Antucheviciene, J.; Kosareva, N. A hybrid model based on fuzzy AHP and fuzzy WASPAS for construction site selection. *Int. J. Comput. Commun. Control* **2015**, *10*, 113. [CrossRef]
37. Chuyển Dịch Năng Lượng Bền Vững tại Đồng Bằng Sông Cửu Long—Bài 1: Xu Thế Tất Yếu và Bền Vững. Available online: https://moit.gov.vn/tin-tuc/70-nam-nganh-cong-thuong/chuyen-dich-nang-luong-ben-vung-tai-dong-bang-song-cuu-long-3.html (accessed on 10 August 2021).
38. Đồng Bằng Sông Cửu Long: Phát Triển Năng Lượng Tái Tạo—Cơ Hội Ứng Phó Biến Đổi Khí Hậu. Available online: http://tnmttuyenquang.gov.vn/tin-tuc/khoa-hoc-cong-nghe!/Dong-bang-song-Cuu-Long-Phat-trien-nang-luong-tai-tao-co-hoi-ung-pho-BDKH-12577.html (accessed on 10 August 2021).