Strategic Optimal Path and Developmental Environment on Photovoltaic Industry in China Based on an AHP-SWOT Hybrid Model

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Abstract. Utilizing the qualitative analysis of SWOT and quantitative method of AHP, this paper presented the AHP-SWOT hybrid model of the photovoltaic industry in China in order to calculate the influence of the strengths, weaknesses, opportunities & threats (SWOT factors and SWOT sub-factors), and the SO strategy, WO strategy, ST countermeasure and WT countermeasure on the development of the photovoltaic industry in China. The results show that the influence of the threats are the most, the weaknesses and opportunities second, and the strengths the least among four SWOT factors of the development of the photovoltaic industry in China. Thereby, among 12 SWOT sub-factors, complete industrial chains are the most important factor in the strengths factors, lack of core technology is of the most significance in the weaknesses factors, latent necessity of the photovoltaic industry development as a result of global energy crisis is the most valuable opportunities factor, and external trade environment deteriorating due to international trade protection is the most threats factor. Among four combination path of the development strategy, the WT countermeasure possesses the most valuable positive influences on the development of the photovoltaic industry in China, which is the optimal path for the strategy alternatives.

Keywords: photovoltaic industry, development strategies, strategic path, AHP, SWOT, China

1 Introduction

After a period of the photovoltaic industry development, China has become one of the world's largest photovoltaic manufacturing countries. However, the capacity of photovoltaic industry in China is given priority to with export, more than 90% of which were obliged to depend on the international market. At present, the export of Chinese photovoltaic industry was impacted because of the global financial crisis and the European debt crisis, and the domestic markets were not completely open so that the development of Chinese photovoltaic industry has been involved in the bottleneck period [1]. China-Eu photovoltaic conflict finally had been resolved through a price undertaking, it also is a wake-up call for Chinese industry development.

In order to find out the problems that photovoltaic industry in China were facing and explore its development strategies, domestic scholars have done a lot of qualitative analysis and statistical description work on photovoltaic industry, which mainly focused on status definition[1], development status, international competitiveness[2], industrial cluster[3], operating and collaborative performance[4, 5], and development strategies. From the perspective of development strategies, however, the quantitative optimization really matters to help to choose the strategic path of photovoltaic industry in China and promote its sustainable development. This paper combined SWOT method with AHP method, which took full advantage of the combination of quantitative and qualitative analysis [6-11]. By using this hybrid method, this paper qualitatively analyzed the strengths, weaknesses, opportunities, and threats (SWOT) of the photovoltaic industry development in China, quantitatively evaluated sub-factors of SWOT and optimized the strategic path of photovoltaic industry development in China.

2 SWOT Analysis of Photovoltaic Industry Development in China

2.1 SWOT Factor Analysis of Photovoltaic Industry Development in China

The photovoltaic industry in China has faced both restrictions and opportunities since 2012. The photovoltaic industry development in China is a complex system affected by national economy and social development. The basic elements of SWOT method consist of strengths, weaknesses, opportunities, and threats. Strengths and weaknesses are internal factors while opportunities and threats are external factors. Utilizing the SWOT method, the factors should be divided into strengths, weaknesses, opportunities, and threats according to the affection on the photovoltaic industry development in China [6, 8, 11].

SWOT analysis matrix was constructed, and contained 12 SWOT factors affecting the photovoltaic industry development in China (Fig.1). Among 12 SWOT factors, there were three SWOT sub-factors for strengths, weaknesses, opportunities, and threats, respectively [8, 9]. In SWOT sub-factors from strengths, there were three factors for Photovoltaic industry is a newly developing resource industry, Complete industrial chains, and Obvious strengths of cluster development in photovoltaic industry; from weaknesses, three factors for The photovoltaic industry chain mainly amassed on the mediate part of low value, Relatively high cost of producing photovoltaic production component, and Lack of core technology; from opportunities, three factors for Government support in photovoltaic industry, Latent necessity of the photovoltaic industry development as a result of global energy crisis, and Juncture of integration in photovoltaic industry; from threats, three factors for The photovoltaic industry chain mainly amassed on the mediate part of low value, Relatively high cost of producing photovoltaic production component, and Lack of core technology.

Strengths ① Photovoltaic industry is a newly developing resource industry ② Complete industrial chains ③ Obvious strengths of cluster development in photovoltaic industry	**Opportunities** ① Government support in photovoltaic industry ② Latent necessity of the photovoltaic industry development as a result of global energy crisis ③ Juncture of integration in photovoltaic industry
Weakness ① The photovoltaic industry chain mainly amassed on the mediate part of low value ② Relatively high cost of producing photovoltaic production component ③ Lack of core technology	**Threats** ① Blind guidance of local government in the photovoltaic industry development ② External trade environment deteriorating due to international trade protection ③ Lack of photovoltaic industry standards

Fig.1. SWOT analysis matrix of the developmental strategy for the photovoltaic industry in China

2.2 Strategy Combination and Path Analysis of the Photovoltaic Industry Development in China

Development strategies could be obtained by combining and adjusting the factors of strengths, weaknesses, opportunities and threats according to the effects on photovoltaic industry system in China. The factors of different strategies could be combined according to the effects, as has the different influence on the photovoltaic industry system in China. According to analysis on the inner strengths, weaknesses and the external opportunities and threats of the photovoltaic industry in China, two strategies of SO strategy, WO strategy and two countermeasures of ST countermeasure, WT countermeasure could be formed by matching the four SWOT factors[8, 9].

The four paths are of different characteristics (Table 1). On basic strategy, SO means aggressive attack, which should take advantages, and seize opportunities. On tactics, strategic measures is to greatly develop the photovoltaic energy industry, further perfect the photovoltaic industry chains, adjust and optimize the government's supporting policies, promote the development of photovoltaic industry, and complete the top design, exert the advantage of cluster development in photovoltaic industry.

ST means corresponding defense, which should take advantages and avoid threats. On tactics, strategic measures is to enhance inter-regional cooperation, reasonably plan area distribution in photovoltaic industry, develop the market in China, set up standards in photovoltaic industry and carry out market access rules, and speed up the integration of photovoltaic industry chains.

WO means gradual advance, which should seize opportunities and change weaknesses. On tactics, strategic measures is to adjust and optimize the industrial structure, integrate the photovoltaic industry, train more qualified staff, increase investment in scientific research, make breakthrough in technology and master core skills in photovoltaic industry, reduce the production cost of photovoltaic products,

and strengthen government's supporting force, improve the top design, positively develop high-end industry chain junction of high additional values.

WT means defense or retreat, which should overcome weaknesses and avoid threats. On tactics, strategic measures is to improve inter-regional cooperation, optimize the structure of photovoltaic industry chain and regional distribution, reduce the reliance upon raw materials on foreign, increase investment, master core technology, reduce the production costs of photovoltaic products, actively explore the domestic market, decrease the dependence on overseas markets, and set up standards and market access system of Chinese photovoltaic industry in order to avoid the disorderly cooperation and blind expansion of photovoltaic industry.

Table 1. Features of the strategic combination of the photovoltaic industry development in China

External enviroment factors / Internal condition factors	**Opportunities (O)**	**Threats (T)**
	① Government support in photovoltaic industry ② Latent necessity of the photovoltaic industry development as a result of global energy crisis ③ Juncture of integration in photovoltaic industry	① Blind guidance of local government in the photovoltaic industry development ② External trade environment deteriorating due to international trade protection ③ Lack of photovoltaic industry standards
Strengths (S)	**SO strategy: aggressive attack (take advantages, seize opportunities)**	**ST strategy: corresponding defense (take advantages, avoid threats)**
①Photovoltaic industry is a newly developing resource industry ②Complete industrial chains ③Obvious strengths of cluster development in photovoltaic industry	① Greatly develop the photovoltaic energy industry ② Further perfects the photovoltaic industry chains ③ Adjust and optimize the government's supporting policies, promote the development of photovoltaic industry ④ Complete the top design, exert the advantage of cluster development in photovoltaic industry	① Enhance inter-regional cooperation, reasonably plan area distribution in photovoltaic industry ② Develop the market in China ③ Set up standards in photovoltaic industry and carry out market access rules ④ Speed up the integration of photovoltaic industry chains
Weaknesses (W)	**WO strategy: gradual advance (seize opportunities, change weaknesses)**	**WT strategy: defense or retreat (overcome weaknesses, avoid threats)**
① The photovoltaic industry chain mainly amassed on the mediate part of low value ② Relatively high cost of producing photovoltaic production component ③ Lack of core technology	① Adjust and optimize the industrial structure, integrate the photovoltaic industry ② Train more qualified staff, increase investment in scientific research, make breakthrough in technology and master core skills in photovoltaic industry, reduce the production cost of photovoltaic products ③ Strengthen government's supporting force, improve the top design, positively develop high-end industry chain junction of high additional	① Improve inter-regional cooperation, optimize the structure of photovoltaic industry chain and regional distribution, reduce the reliance upon raw materials on foreign ② Increase investment, master core technology, reduce the production costs of photovoltaic products, actively explore the domestic market, decrease the dependence on overseas markets ③ Set up standards and market access system of Chinese photovoltaic industry in order to avoid the disorderly cooperation

	values	and blind expansion of photovoltaic industry

3 Construction of the SWOT-AHP Model of Photovoltaic Industry Development in China

3.1 The SWOT-AHP Model of Photovoltaic Industry Development in China

Based on the goal of sustainable development of photovoltaic industry in China, the SWOT-AHP model of photovoltaic industry development in China was constructed within the theoretical logic framework of the analysis on system factors and factor weight, decision making and strategy choice (Fig. 1)[8, 9].

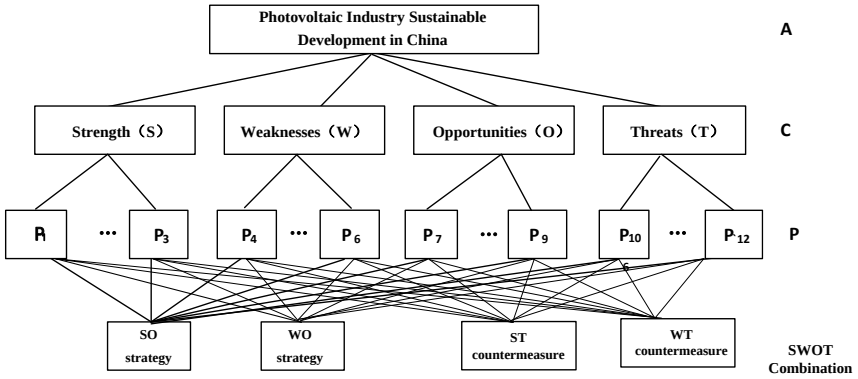

Fig.2. The SWOT-AHP model of photovoltaic industry development in China

According to the general goal of the photovoltaic industry development in China, a bottom-up hierarchy was constructed. The top level was the objective level which is the sustainable development of the photovoltaic industry. The basic elements of SWOT analysis were middle constraining elements, which constituted the criteria level. The bottom level was the strategy combination of the photovoltaic industry development in China, which was the alternatives level [8, 9].

3.2 The Comparison Matrix by Layers

Between layer A and C showed in Fig.1, the comparison matrix of A-C layer can be established as $A=(c_{ij})_{n\times n}$, whose elements are evaluated using a 9-point scale. The paired comparison of element i with element j in the C layer is placed in the position of C_{ij} of the comparison matrix of A-C layer [6, 7].

The comparison matrix is a square matrix as $A=(c_{ij})_{n\times n}$, and:

$$c_{ij}>0;\quad c_{ij}=1/c_{ji};\quad c_{ii}=c_{jj}=1 \tag{1}$$

Similarly, the comparison matrix of C-P layers can be obtained in the same method used in forming the comparison matrix of A-C layers. Data on paired comparison matrices were collected from reviewers. Scores of c_{ij} were estimated on the average by inviting the field experts. The participating decision makers provided paired comparisons for each level of the hierarchy in order to obtain the weight factors of each element on that level, and with respect to one element in the next higher level [6, 7].

3.3 Overall Rank of the Hierarchical Level

Single ranks of the hierarchical level are used to calculate the importance of the elements of layer k+1 to layer k (meaning each element of C to A and P to C in this paper), and the elements of every layer are ranked according to the relative score of the paired comparisons [11].

The consistency index (CI) was calculated based upon the maximum eigenvalue. The consistency ratio (CR) is calculated by dividing the CI by the ratio index (RI). The CR has to be lower than 0.1, otherwise the matrix will be considered inconsistent. If the matrix is inconsistent, the eigenvector generated from this matrix will be rejected [11].

The overall rank of the hierarchical level is the important ranking of the elements of the strategy combination (SO, WO, ST, WT) to the general objective of A. The method algorithm is shown as Table 2.

Table 2. Calculation method for overall ranking of the hierarchical level

Items		C_1	C_2	C_3	C_4	Single ranks of A–P
		W_{C_1}	W_{C_2}	W_{C_3}	W_{C_4}	$\sum_{i=1}^{4} W_{C_i} W_{P_j^i}$ (j = 1,2,..., n)
	P_1	$W_{P_1^1}$	$W_{P_1^2}$	$W_{P_1^3}$	$W_{P_1^4}$	$\sum_{i=1}^{4} W_{C_i} W_{P_1^i}$
	P_2	$W_{P_2^1}$	$W_{P_2^2}$	$W_{P_2^3}$	$W_{P_2^4}$	$\sum_{i=1}^{4} W_{C_i} W_{P_2^i}$
P	⋮	⋮	⋮	⋮	⋮	⋮
	P_n	$W_{P_n^1}$	$W_{P_n^2}$	$W_{P_n^3}$	$W_{P_n^4}$	$\sum_{i=1}^{4} W_{C_i} W_{P_n^i}$
	Σ	1.00	1.00	1.00	1.00	1.00
Overall rank of the hierarchical level	SO					$\left(\sum_{i=1}^{4} W_{C_i} W_{P_j^i} \ (j = 1,2,..., n)\right) * W_{so}$
	WO					$\left(\sum_{i=1}^{4} W_{C_i} W_{P_j^i} \ (j = 1,2,..., n)\right) * W_{wo}$
	ST					$\left(\sum_{i=1}^{4} W_{C_i} W_{P_j^i} \ (j = 1,2,..., n)\right) * W_{sT}$
	WT					$\left(\sum_{i=1}^{4} W_{C_i} W_{P_j^i} \ (j = 1,2,..., n)\right) * W_{WT}$

Notes：In the SWOT-AHP model of photovoltaic industry development in China, n represented the numerical value of SWOT Sub-factors in index alternatives, for 12 in this paper.

4 Calculation Results of the SWOT-AHP Model of Photovoltaic Industry Development in China

Invite the experts, scholars and managers participating in the survey, and filling the strategic survey questionnaires of photovoltaic industry development in China in order to relative importance of the SWOT elements.

4.1 Single Ranks of the Hierarchical Level and Consistency Test

(1)A-C Single ranks
According to the calculating method above, the weights of the middle level to the top level can be figured out, the results was shown in Table 3:

Table 3. The comparison matrix of A-C layer

A	C_1	C_2	C_3	C_4	Weights of the middle level
C_1	1.0000	0.4727	0.7091	0.3406	0.1340
C_2	2.1154	1.0000	1.5000	0.7205	0.2835
C_3	1.4102	0.6667	1.0000	0.4803	0.1890
C_4	2.9360	1.3880	2.0820	1.0000	0.3935

Consistency test: λ_{max} =4.000123, CI=(4.000123-4)/3 = 0.000041, RI = 0.882（Obtained by looking up tables，the same below），CR= CI / RI =0.000041/0.882 =0.000046 <0.1(Pass the consistency test)。

(2) C-P Single ranks

The weights of indexes in the alternative level to indexes in the criteria level were shown in Table 4. The CRs were 0.0003, 0.0001, 0.0001and 0.0001, which meant that the results all passed consistency test.

(3) P-SWOT Single ranks

The weights of indexes in the alternative level to indexes in the bottom level were shown in Table 4. The CRs were 0.000077, 0.000179, 0.000009, 0.000188, 0.000109, 0.000069, 0.000041, 0.000267, 0.000240, 0.000338, 0.000017 and 0.000098, which meant that the results all passed consistency test.

4.2. Overall Rank of the Hierarchical Level

The weights of four strategies in bottom level to the sustainable development of the photovoltaic industry were shown in Table 4.

Table 4. The overall ranking results of the hierarchical level

SWOT factors	A-C weights	CR	SWOT sub-factors	C-P weights	A-P weights	P-SWOT Weights				
						SO	WO	ST	WT	CR

			P_1	0.3316	0.0444	0.3886	0.2976	0.1984	0.1154	0.011505
S	0.1340	0.0003	P_2	0.4538	0.0608	0.3400	0.2330	0.2913	0.1356	0.003067
			P_3	0.2145	0.0287	0.3515	0.2182	0.2500	0.1803	0.031795
			P_4	0.2501	0.0709	0.1157	0.2975	0.1704	0.4163	0.053029
W	0.2835	0.0001	P_5	0.3262	0.0925	0.0664	0.3357	0.1923	0.4056	0.052427
			P_6	0.4237	0.1201	0.0624	0.3757	0.1205	0.4414	0.076473
			P_7	0.3100	0.0586	0.3697	0.2848	0.2118	0.1337	0.033883
O	0.1890	0.0001	P_8	0.5195	0.0982	0.5064	0.3157	0.1230	0.0549	0.038559
			P_9	0.1705	0.0322	0.3978	0.3099	0.2195	0.0727	0.040398
			P_{10}	0.3100	0.1220	0.0803	0.1732	0.3283	0.4181	0.069052
T	0.3935	0.0001	P_{11}	0.5195	0.2044	0.1326	0.2286	0.2723	0.3665	0.081185
			P_{12}	0.1705	0.0671	0.1212	0.1806	0.3176	0.3806	0.054057
A-SWOT Weights						0.1991	0.2686	0.2266	0.3056	

5 Strategic Path Selection of Photovoltaic Industry Development in China

5.1 Effects Analysis of the SWOT Factors

The analysis results of the SWOT factors showed that the rank order of four SWOT factors was threats >weaknesses>opportunities>strengths based on the degree of influence. The results stated that the threats and weaknesses faced by photovoltaic industry development in China were obvious. The threats had great influence on photovoltaic industry development in China while strengths had the little influence.

In the strengths group of SWOT, the rank order of the factors was P_2> P_1>P_3, the greatest advantage was complete industrial chains. The second greatest advantage was Photovoltaic industry for a newly developing resource industry. The least advantage was obvious strengths of cluster development in photovoltaic industry.

In the weaknesses group, the rank order of the factors was P_6>P_5>P_4, the biggest weaknesses was Lack of core technology. The second biggest weakness was relatively high cost of producing photovoltaic production component. The third biggest weakness was the photovoltaic industry chain mainly amassed on the mediate part of low value.

In the opportunities group, the rank order of the factors was P_8>P_7>P_9, the biggest opportunity was latent necessity of the photovoltaic industry development as a result of global energy crisis. The second biggest opportunity was government support in photovoltaic industry. Juncture of integration in photovoltaic industry was at the last, which had the smallest influence.

In the threat group, the rank order of the factors was $P_{11}>P_{10}>P_{12}$, the biggest threat was external trade environment deteriorating due to international trade protection. The second biggest threat was lack of photovoltaic industry standards. Blind guidance of local government in the photovoltaic industry development was at the last, which had the smallest influence.

5.2 Selection of Strategic Path Combination

The results in Table 4 showed that the weights of the four combinations (SO strategy, WO strategy, ST countermeasure and WT countermeasure) was 0.1991, 0.2686, 0.2266, 0.3056, which meant that the rank order was WT countermeasure>WO strategy > ST countermeasure >SO strategy. The results showed WT countermeasure or WO strategy were the better choices than anyone of SO strategy and ST countermeasure, and the WT countermeasure was the best choice.

6 Conclusions

According to the SWOT-AHP quantitative analysis of photovoltaic industry development in China, WT countermeasure and WO strategy were the better choice, and the WT countermeasure was the best choice. The basic strategy is to choose the WT countermeasure as the strategic optimal path in order to overcome weaknesses and avoid threats. On tactics, strategic measures is to strengthen the regional cooperation, optimize the structure of photovoltaic industry chain and regional distribution, reduce the dependence of raw materials on foreign; to increase investment, master the core technology, reduce the production costs of photovoltaic products, actively explore the domestic market; to set up the standards and market access system of Chinese photovoltaic industry in order to avoid the disorderly competition and blind expansion of photovoltaic industry.

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