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# Research on Influencing Factors of Cost Control of Centralized Photovoltaic Power Generation Project Based on DEMATEL-ISM

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**Abstract:** The high cost of centralized photovoltaic power generation projects is an important problem affecting industrial development, which needs to be solved urgently. It is particularly important to explore the influencing factors of cost control and the interaction between them. This paper takes a centralized photovoltaic power generation project as the research object, and determines the index system of influencing factors of cost control from the perspective of the life cycle. Secondly, the logical relationship between influencing factors is judged by the method of combining DEMATEL (decision-making trial and evaluation laboratory) and ISM (interpretive structural modelling). Finally, the multi-order recursive interpretation structure model is obtained, and the action mechanism between various factors is obtained. The results show that national policies and standards are the most profound influencing factors, and their cause degree reaches 2.155; the reason degree of market changes is the second, which is 1.586; bidding and contract management are the factors with the highest centrality, which is 7.120; and transmission and the storage of electricity and equipment repair and maintenance are the most direct factors affecting cost control. Finally, some suggestions are put forward for different types of influencing factors. The research results can better help photovoltaic power generation enterprises solve the problem of cost control.

**Keywords:** centralized photovoltaic power; cost control; DEMATEL; ISM



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## 1. Introduction

With the positive and negative experiences and lessons of modernization development since the industrial revolution, people have gradually realized that relying on the high-carbon growth models with fossil energy as the main source has seriously threatened environmental security, and it is imperative to take a low-carbon and sustainable green development path. Photovoltaic power generation, as a clean energy source, does not produce carbon emissions and pollution and has a unique advantage of environmental friendliness compared with other fossil energy sources [1]. Some scholars put forward that solar energy resources should be applied to power generation in daily life [2]. Centralized photovoltaic power generation is a form of photovoltaic power generation. Compared with distributed photovoltaic power generation, it can be built on a large area of land to realize large-scale power supply, which has important economic and environmental significance for the development of renewable energy. In recent years, with the continuous progress of photovoltaic power generation technology, the technical cost of centralized photovoltaic power generation projects has gradually decreased [3]. However, the cost problems caused by land resource supply, power grid connection, and operation and maintenance in the construction process need to be actively promoted by relevant departments and enterprises. Therefore, it is of great significance to explore the influencing factors of cost control of centralized photovoltaic power generation projects and their mechanism for promoting the development of the photovoltaic power generation industry, promoting the development of clean energy, and then promoting the construction of ecological civilization and Sustainable Development Goals (SDGs) [4].

At present, the research on centralized photovoltaic power generation mainly focuses on the cost of electricity [5], benefit analysis and evaluation [6], power generation efficiency [7,8], carbon emission [9], environmental impact [10], and so on, and there is little research on the influencing factors and their mechanism of cost control in the whole life cycle of centralized photovoltaic power generation. Mustafa et al. [11] identified the key factors that affect the implementation of photovoltaic power generation projects through multiple linear regression models (MLRMs) and rule-based decision support systems (RBDSSs). In the research, Shukla A K et al. [12] analysed the obstacles to solar photovoltaic application, including efficiency, building photovoltaic integration, cost, and power storage, and put forward relevant policy suggestions. Jiang M [13] put forward a new concept on the cost of photovoltaic power generation, that is, using the existing photovoltaic power generation infrastructure to reduce the cost related to the increase in land use, and combining coal-fired power plants with photovoltaic power generation to absorb the power resources that cannot be transported. The learning curve research method to reduce the cost is more and more favoured by scholars. Zhang et al. [14] used a learning curve model to study the future cost change trend of centralized photovoltaic power generation. From the perspective of environmental costs, factors such as the material selection and production technology of photovoltaic modules [15], the cutting technology of polysilicon power generation systems [16], the transportation of components and equipment, the attenuation degree and maximum output power of photovoltaic power generation systems [17], and waste disposal technology [9] will lead to carbon emission differences. In the cost composition, photovoltaic modules and equipment account for the largest proportion. Therefore, some scholars have studied the influence of dust accumulation and installation inclination on the output power of photovoltaic modules and carried out regional clustering with dust deposition influencing factors [18]. With the increase in installed capacity, the energy storage system has gradually developed, among which pumped storage is the most economical energy storage method at present, and its operating years and installed scale will also affect the total cost of photovoltaic power plants [19]. Muhammad [20] put forward a strategy based on hierarchical rolling time domain control, which can effectively manage the hydrogen energy storage system in the island wind–solar microgrid and discussed the economy and operation cost of the energy storage scheme of multiple hydrogen storage tanks. At the same time, the research also inspires us to consider using the energy storage system composed of electrolytic cells and fuel cells to solve the power fluctuation problem that may occur in grid connection, and to find the optimal controller to solve the smooth tracking problem of output power fluctuation and load demand [21]. The above research not only shows the important position of solar energy resources in energy but also enriches the theoretical basis of the research on the influencing factors of centralized photovoltaic power generation cost control. Through the study of various cost control methods, the methods and models suitable for different industries and projects are summarized, and many practical cost problems are solved. At present, cost control pays more and more attention to the management of the whole project process, and also pays more attention to case analysis and empirical research, mainly focusing on the research of cost management Informa ionization, and technological progress. However, the existing research involves a single level of construction stage, considering the single influence of a certain stage or a certain aspect, and fails to study the influencing factors of cost control from the perspective of the whole life cycle of project construction, and is unable to explore the correlation and mechanism of influencing factors in each stage of project construction.

There are qualitative and quantitative methods to analyse the influencing factors in the existing research. The qualitative methods mainly include the Delphi method [22], ISM method [23], and text mining [24], and the quantitative methods include the FCM method [25], analytic hierarchy process [26], structural equation model [27], and system dynamics [28]. Xiang et al. [23] applied the ISM method to the cost control of prefabricated buildings, constructed the cost impact index system of prefabricated buildings, and obtained five influencing factors with great cost impact [23]. The ISM method can explore the relationship between different factors, but it lacks the determination of key factors. Ying et al. [27] used SEM to analyse the influencing factors of cost control of construction projects and found that organizational management has the greatest influence on cost control. SEM needs to establish a model based on certain theoretical assumptions and determine the relationship through the verification of the model. However, for complex systems, the complexity of the model will also increase, which will increase the difficulty of model interpretation. In recent years, the application of system dynamics in engineering research has become more and more extensive. Yijun et al. [29] used system dynamics to build a simulation model for the evolution of economic benefits of energy storage on the side of new energy generation and considered that the capacity of energy storage power stations, the price difference between peak and valley and the cost of energy storage technology are important factors affecting the economy. The method of system dynamics focuses on the simulation and prediction of the system, and mainly considers the influence of internal factors of the system and ignores external factors. For the centralized photovoltaic power generation project, the cost control of each stage in the whole life cycle is interrelated, with a large number and a wide range, which has a certain fuzziness and uncertainty. When studying influencing factors, we should not only analyse the importance of each influencing factor but also clarify the causal relationship between them. The existing research methods cannot meet the research needs well. So, some scholars put forward to combine graph theory with matrix theory to carry out systematic decision-making experiments and evaluation experiments (DEMATEL) and apply it to the research field of influencing factors to reveal the causal relationship between factors and the degree of influence [30,31]. In a system with many influencing factors, the hierarchical relationship between factors cannot be well expressed. Therefore, interpretative structural modelling (ISM) is introduced to identify the relationship between factors and further analyse the importance of influencing factors at all levels. ISM can simplify the complex system, divide the system levels, qualitatively analyse the influence relationship between each influencing factor, and reveal the internal structure of the system by using the relationship between system elements. Based on the commonness, advantages, and disadvantages of DEMATEL and ISM methods, DEMATEL can reduce the complexity and calculation amount of a reachable matrix, and its comprehensive influence matrix contains more value information than a reachable matrix, which can make up for the shortcomings of ISM, and ISM can acquire a clearer hierarchical structure division of complex systems, so the integrated DEMATEL-ISM model has unique advantages in complex system analysis. The method of combining DEMATEL with ISM is beneficial to combine quantitative and qualitative methods and to better judge and analyse the relationship between factors.

There are still many possibilities for cost optimization in the construction of centralized photovoltaic power generation projects, which should be discussed in different construction stages, both from the technical level and the management level. At present, scholars rarely explore the influencing factors of cost control and their action paths from the whole process of project construction, and most of the research methods of influencing factors in the existing literature cannot effectively identify the key factors and consider their action paths. In view of this, the life cycle perspective proposed in this paper can explore the influencing factors of centralized photovoltaic power generation cost control completely and comprehensively, and based on the management perspective, explore the possibility of management cost reduction under the background of declining technology costs; Secondly, the source and action path of each factor are different. Using the DEMATEL method, we can find out the influence relationship between the influencing factors and analyse the action mechanism of cost control, and finding out the most important factor in the whole project construction process is one of the focuses of this paper. Finally, the multi-level recursive model based on ISM analysis can sort out the influencing factors at all levels and provide a theoretical basis for cost control suggestions. The conclusion of this paper can enrich the theoretical research on cost control of centralized photovoltaic power generation projects and provide ideas for cost control for relevant practitioners from the perspective of management.

The possible contributions of this paper are as follows:

1. From the perspective of the life cycle, this paper analyses the different factors that affect cost control from the decision-making stage, design stage, and construction stage to the operation and maintenance stage, considers some uncontrollable factors that run through the whole cycle of project construction, and constructs the index system of influencing factors.
2. On the basis of the index system, using the DEMATEL-ISM method, the empirical data are obtained through a questionnaire survey, the centrality and cause degree of each factor are obtained, the logical relationship and importance of each factor are sorted out, and a multi-level recursive explanation structure model is established to sort out the hierarchical relationship between factors.
3. Based on the results of DEMATEL analysis and the multi-step recursive explanation structure model, the deepest cause, the most important factor in the transition layer, and the shallow cause are analysed, and effective measures for cost control of centralized photovoltaic power generation projects are put forward from these four aspects, and practical management means are put forward from the perspective of all participants, which provides a reference for promoting the development of centralized photovoltaic power generation projects.

## 2. Construction of Influencing Factors System of Cost Control

Based on the research background and theoretical basis, in the analysis and research on the life cycle cost of photovoltaic power generation projects, there are many influencing factors of its cost control and the subjects involved, so there are many types of indicators and different subjects. This paper preliminarily identifies the influencing factors of cost control involved in many documents by means of a study of the literature and classifies them according to their respective stages after interpreting the connotation. In a narrow sense, the life cycle of a project is generally divided into a decision-making stage, design stage, construction stage, and operation and maintenance stage. According to the construction process of a centralized photovoltaic power generation project, the stage of influencing factors is judged. Among them, national policies and standards, market changes, natural environmental factors, and so on are determined by the macro environment and cannot be divided into a certain stage, so they are independent of the controllable factors divided by stages. The following will explain the identified influencing factors:

(A) Controllable Factors

1. Decision Stage: Construction site selection is an important factor in determining the construction of the project, which determines the convenience of the construction and operation stages. The lighting resources, convenient transportation, and topographic and geological conditions should be considered as much as possible. The situation of power grid access and load consumption needs to be fully investigated at this stage, and it is generally necessary to pay attention to the local power grid structure and voltage level. Preliminary survey and detection is an important means to collect data, which is conducive to preparing for post-design and needs to comprehensively consider technical, environmental, economic, and social factors to ensure the smooth implementation and long-term operation of the project. In addition to observing the compliance points of planned land use, the land occupation cost and compensation cost should be fully calculated. When deciding to invest, it is necessary to consider financing costs and loan methods, broaden various financing channels, and choose the loan repayment method with the lowest interest expense.
2. Design Stage: Before the preliminary design is carried out, the owner should invite tenders for the main equipment. Equipment procurement is the largest part of the cost expenditure, and the reliable equipment supplier and the most

cost-effective equipment should be selected by integrating its various elements. The design scheme of the power station includes the planning of the production area and living area, the layout of the photovoltaic area and booster station, and the overall design should consider whether the investment cost and power generation can meet the requirements. The layout of the battery assembly and the installation mode of the bracket mainly include the selection of array mode and tracking system. The design depth is to deepen the preliminary design, deepen the design from site selection, resource conditions, equipment selection, power consumption, and other aspects, do a good job in technical scheme demonstration, and consider the possible environmental, economic, and administrative risks in construction projects. The light available hours are mainly affected by the light resources in the construction area, but the effective hours can be improved by reasonably selecting the installation mode of photovoltaic modules and regular cleaning and maintenance. In bidding and contract management, we should choose the appropriate bidding method, strictly manage the bidding procedures, scientifically evaluate and determine the bid, consider the risks and interests of both parties when signing the contract, avoid contract disputes, abide by the contract provisions in the performance process, and make timely adjustments when changes occur.

3. Construction Stage: On-site construction management includes doing a good job in construction organizational design, personnel management, and formulating various on-site construction management systems, such as a safety management system, material management system, quality management system, financial approval system, etc. Construction machinery management mainly refers to ensuring the smooth transportation process of machinery, reasonably arranging the application scope and entry and exit of machinery and equipment, ensuring the balanced use of machinery, and doing a good job in machinery maintenance. Construction progress management includes reasonably using critical path methods to determine the sequence and relationship of each work, optimizing the logical relationship between processes by using new materials or new technologies, monitoring and tracking the progress, and handling the progress deviation in time.
4. Operation and Maintenance Stage: The larger the scale of the project, the more types and quantities of equipment involved, the greater the workload of analysis and maintenance, and the corresponding increase in labour costs. Centralized photovoltaic power generation is generally far away from the electricity consumption area, so it is necessary to build a transmission system to complete the transmission of electricity, and if necessary, it is necessary to equip a power storage system. At present, the power storage methods include battery energy storage, supercapacitor energy storage, mechanical energy storage, etc. Equipment failure is an important reason for power loss and cost expenditure in the power station operation and maintenance stage. Establishing a perfect operation and maintenance management system, including equipment inspection, fault handling, and data monitoring, can reduce the failure rate and effectively control the cost.

(B) Uncontrollable Factors

1. National policies and standards: The development of the industry mainly depends on the photovoltaic industry policy, and the national overall planning promotes the expansion of photovoltaic scale and cost reduction. Local policies determine the specialization and subdivision development of photovoltaics. For the land factors that have the greatest impact on the centralized photovoltaic power generation project, the government can guide the project to combine with agriculture and forestry through policies to avoid expenses such as farmland occupation tax and forest land compensation.

2. Market changes: The current trading mode of centralized photovoltaic power generation in the country is different in different provinces, but most of them are consumed according to the power guarantee within the guarantee ratio, and the rest enter the market to participate in market-oriented transactions. Such a trading mechanism is conducive to reflecting the elasticity of power production cost and power demand, with strong timeliness, and is conducive to the coordination of the market mechanism of the power industry chain. In addition, market mechanism innovations such as electronic green certificate trading and renewable energy quota restriction can promote the rapid development of the photovoltaic power generation market and power consumption.
3. Natural environment factors: Unpredictable weather will hinder the construction, operation, and maintenance to a certain extent, which will prolong the construction period and increase the cost. Other natural environmental factors, such as complex terrain and remote geographical location, will increase the transportation cost during construction and the maintenance cost during operation and maintenance.

In this article, the influencing factors are divided into controllable and uncontrollable from the perspective of cost management. The controllable factors are divided into four stages, including 17 factors, and the uncontrollable factors include 3 factors, with a total of 20 factors selected. Combined with the opinions of construction site managers, experts in the photovoltaic power generation field, and university professors, a preliminary influencing factor system of photovoltaic power generation cost control is constructed, as shown in Table 1.

**Table 1.** System of influencing factors for cost control of centralized photovoltaic power generation project.

| Partitions | | Number | Influencing Factor | Source |
|---|---|---|---|---|
| Controllable Factors | Decision Stage | $X_1$ | Construction site selection | [32,33] |
| | | $X_2$ | Traffic and grid-connected state | [33–36] |
| | | $X_3$ | Survey and detection | [37,38] |
| | | $X_4$ | Cost of land use | [30,37,39,40] |
| | | $X_5$ | Financing conditions and loan methods | [5,35,37,41,42] |
| | Design Stage | $X_6$ | Equipment procurement management | [43] |
| | | $X_7$ | Design scheme of photovoltaic power station | [35,44] |
| | | $X_8$ | Layout of battery assembly and the installation mode of bracket | [45,46] |
| | | $X_9$ | Depth of design | [38,47] |
| | | $X_{10}$ | Light available hours | [41,48] |
| | | $X_{11}$ | Bidding and contract management | [38] |
| | Construction Stage | $X_{12}$ | Site construction management | [49,50] |
| | | $X_{13}$ | Construction machinery management | [49] |
| | | $X_{14}$ | Construction schedule management | [49,50] |
| | Operation and Maintenance Stage | $X_{15}$ | Project scale | [5,48] |
| | | $X_{16}$ | Power transmission and storage | [36,38] |
| | | $X_{17}$ | Repair and maintenance of equipment | [30] |
| Uncontrollable Factors | | $X_{18}$ | National policies and standards | [34,44,51] |
| | | $X_{19}$ | Market changes | [44] |
| | | $X_{20}$ | Natural environment factors | [44] |

## 3. DEMATAL-ISM Methodology

There are many factors influencing the cost control of centralized photovoltaic power generation, and the relationship between them is complex. How to effectively identify the action path of cost control and find out the key influencing factors of cost control requires the methods of clear relationship and factor identification. The evaluation index system of influencing factors of centralized photovoltaic power generation cost includes 20 factors in five aspects. The influencing factors are determined according to different paths and aspects in the identification stage, which are theoretically not overlapping and independent, but the influencing factors are still internally related, including different influencing factors in the same aspect and different influencing factors in different aspects. In view of the fact that there are many factors influencing the assembly cost, and there may be internal relations among them, in order to obtain a multi-level progressive structure model of the influencing factors, 20 influencing factors of centralized photovoltaic power generation cost are regarded as a complex network with intricate internal relations among the influencing factors. DEMATEL-ISM is a compound model based on DEMATEL and ISM, which can be used complementarily due to the similarity of principles.

The DEMATEL method is a decision support system, which focuses on the combination of matrix and graph theory to judge the strength of influencing factors and can analyse the relationship between different factors and identify key influencing factors. ISM focuses on qualitative analysis, which is suitable for complex systems with complicated elements, unclear relationships, and unclear structures. It can analyse the subjective imagination with chaotic thoughts into a multi-layer progressive structural model and present the logical relationship among factors intuitively. Combining the advantages and disadvantages of the two methods, this study first uses DEMATEL to construct the relationship between influencing factors and then obtains the influence degree, influenced degree, cause degree, and centrality of influencing factors, identifies the factors with the highest centrality, introduces ISM on the basis of DEMATEL, divides the system levels, and qualitatively analyses the influence relationship between each influencing factor. The specific implementation steps are as follows:

Step 1: Analyse system factors.

Number the factors in the system and let $X_i \in X(X = 1, 2, \ldots, n)$, where $n$ is the number of factors in the system and $X$ is the set of factors in the whole system.

Step 2: Construct the direct influence matrix $A$.

According to the influence factor system of centralized photovoltaic power generation project cost control, the direct influence matrix $A$ is determined. Among them, $a_{ij}$ represents the direct influence of factor $X_i$ on $X_j$, and when $_{i\,=\,j}$, $a_{ij}$ is 0.

$$A = \begin{bmatrix} 0 & \mathrm{a}_{12} & \ldots & a_{1n} \\ a_{21} & 0 & \ldots & a_{2n} \\ \ldots & \ldots & 0 & \ldots \\ a_{n1} & a_{n2} & \ldots & 0 \end{bmatrix}$$

In order to quantify the strength of the influence relationship between various factors, the evaluation scale of the influence relationship between the range (0–5) is set, as shown in Table 2.

**Table 2.** Evaluation scale of impact relationship.

| Influence Relationship | Nothing | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|---|
| Scale | 0 | 1 | 2 | 3 | 4 | 5 |

Relevant experts in the field of centralized photovoltaic power generation are selected to issue questionnaires, and considering the differences in different experts' opinions, the questionnaire results are summarized and averaged statistically to determine the final value of each element in the direct influence matrix $A$, and the relationship between influencing factors is preliminarily determined accordingly.

Step 3: Calculate the normalized direct influence matrix $B$.

In order to eliminate the influence of different dimensions, matrix $A$ is normalized to obtain matrix $B$, and the calculation formula is shown in Formula (1).

$$B = \left[b_{ij}\right]_{n\times n}, a_{ij} \in [0,1], \max_{1\le i\le n}\sum_{j=1}^{n} b_{ij} = 1.$$

$$B = \frac{1}{\max\limits_{1 \le i \le n}\sum_{i=1}^{n} a_{ij}} \quad (1)$$

Step 4: Find the comprehensive influence matrix $Z$.

Clear the influence degree of each factor on other factors in the influencing factor system of centralized photovoltaic power generation project cost control, that is, the accumulation of direct influence and indirect influence. The calculation formula is shown in Formula (2). $I$ is the identity matrix.

$$Z = \lim_{k\to\infty}\left(B + B^2 + \ldots + B^K\right) = \lim_{k\to\infty} B\frac{1 - B^{K-1}}{1 - B} = B(I - B)^{-1} \quad (2)$$

Step 5: Calculate and analyse relevant indicators.

Calculate relevant indicators to determine the total influence degree $f_i$, total influenced degree $e_i$, centrality degree $m_i$, cause degree $n_i$, category attribute, and importance degree of each influencing factor. The calculation formula is shown in Formulas (3)–(6). Centrality $m_i$ indicates the importance of this factor, and the larger the value, the more important it is, and vice versa. Cause degree $\mathrm{n_i}$ indicates the influence degree of this factor on other factors, and if $n_i$ is positive, it indicates that this factor easily influences other factors, which is the cause factor; if $n_i$ is negative, it means that this factor is easily influenced by other factors and is the result factor.

$$f_i = \sum_{i=1}^{n} c_{ij} \quad (3)$$

$$e_j = \sum_{j=1}^{n} c_{ji} \quad (4)$$

$$m_i = f_i + e_j \quad (5)$$

$$n_j = f_i - e_j \quad (6)$$

Step 6: Draw the causal attribute map of factors.

Establish a Cartesian coordinate system, where mi is the abscissa and $n_i$ is the ordinate, and draw a causal attribute map of system factors. Determine the key factors from the causal attribute analysis of factors.

Step 7: Introduce the threshold $\lambda$ to obtain the reachability matrix $K$.

In order to remove the less influential factors in the overall influence matrix $T$ and obtain a clearer multi-order recursive structure model, the system structure is simplified by the threshold $\lambda$, and the values of each element in the reachability matrix are specified, as shown in Formula (7). In order to make the value of the threshold $\lambda$ more objective and reliable, the methods for determining the threshold in the existing literature mainly include the mean method [52], median method [53], quartile method [54], mean and standard deviation method [55], etc. Later, the value of $\lambda$ will be finally determined by combining the stratification results with the actual situation. The determination of elements in the reachability matrix is shown in Formula (7), where $k_{ij}$ and $t_{ij}$ are the elements of the reachability matrix $K$ and the overall influence matrix $T$, respectively.

$$k_{ij} = \begin{cases} 0 & k_{ij} < \lambda \\ 1 & k_{ij} \ge \lambda \end{cases} \quad (7)$$

Step 8: ISM multi-level hierarchical structure model establishment.

The reachability matrix $K$ is processed by multi-level processing, and a multi-level hierarchical interpretation structure model is obtained. Determine the reachable set $R(x_i)$, the antecedent set $Q(x_i)$, and the common set $L(x_i)$ of each factor, where the reachable set $R_i$ represents all factors directly or indirectly affected by an element $X_i$, the antecedent set $Q_i$ represents all elements directly or indirectly affected by an element $X_i$, and the common set represents the intersection of the reachable set and the antecedent set. $R(X_i)$ represents the set of column elements with $k_{ij}$ = 1 in the row corresponding to reachability matrix $K$, and $Q(X_i)$ represents the set of row elements with $k_{ij}$ = 1 in the column corresponding to reachability matrix $K$. The hierarchical division step: extract the elements satisfying $L(X_i)$ = $R(X_i)$ and put them at the top of the ISM structural model, and delete the hierarchical elements again, and repeat the above steps until all the influencing factors are divided.

$$R(X_i) = \{X_i | X_i \in X,\ K_{ij} = 1\} \tag{8}$$

$$Q(X_i) = \{X_i | X_i \in X,\ K_{ji} = 1\} \tag{9}$$

$$L(X_i) = \{X_i | R(X_i) \cap Q(X_i) = L(X_i)\} \tag{10}$$

## 4. Construction of Influencing Factors Model of Cost Control

### *4.1. Data Collection and Determination of Comprehensive Influence Matrix*

Based on the index system of influencing factors of centralized photovoltaic power generation project cost control, the survey objects selected in this study are from five related fields, universities, construction units, construction units, design consulting units and investment and construction units, and 20 experts in related fields of centralized photovoltaic power generation are invited to rate the influence intensity of influencing factors according to a scoring method of 0–5 (0–5 indicates no influence, very low, low, medium, high, and very high, respectively). In total, 17 valid questionnaires were collected, and the effective rate was 85%. According to the data of 17 samples in the questionnaire survey, the direct influence matrix $A = [a_{ij}]_{i*j}$ is constructed, where $a_{ij}$ indicates the influence degree of $X_i$ on $X_j$, and when $i = j$, $a_{ij} = 0$. Using Formula (1), matrix A is normalized to obtain the normalized influence matrix $B$. After obtaining the normalized matrix, in order to show the influence degree among the influencing factors, the comprehensive influence matrix $Z$ is obtained by using Formula (2) in combination with an identity matrix, as shown in Table 3.

**Table 3.** Comprehensive influence matrix Z.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{15}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $X_{19}$ | $X_{20}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 0.16 | 0.14 | 0.10 | 0.28 | 0.25 | 0.13 | 0.14 | 0.10 | 0.10 | 0.12 | 0.26 | 0.15 | 0.24 | 0.25 | 0.20 | 0.25 | 0.22 | 0.08 | 0.14 | 0.28 |
| $X_2$ | 0.17 | 0.09 | 0.07 | 0.17 | 0.14 | 0.10 | 0.11 | 0.07 | 0.12 | 0.07 | 0.21 | 0.11 | 0.18 | 0.20 | 0.11 | 0.17 | 0.19 | 0.06 | 0.06 | 0.22 |
| $X_3$ | 0.13 | 0.07 | 0.04 | 0.12 | 0.09 | 0.06 | 0.06 | 0.04 | 0.04 | 0.04 | 0.12 | 0.08 | 0.10 | 0.12 | 0.10 | 0.10 | 0.11 | 0.04 | 0.04 | 0.10 |
| $X_4$ | 0.22 | 0.11 | 0.07 | 0.18 | 0.23 | 0.15 | 0.19 | 0.08 | 0.09 | 0.07 | 0.17 | 0.19 | 0.24 | 0.23 | 0.13 | 0.23 | 0.16 | 0.06 | 0.07 | 0.26 |
| $X_5$ | 0.19 | 0.10 | 0.06 | 0.23 | 0.13 | 0.10 | 0.10 | 0.07 | 0.07 | 0.06 | 0.17 | 0.16 | 0.21 | 0.20 | 0.11 | 0.19 | 0.12 | 0.06 | 0.06 | 0.19 |
| $X_6$ | 0.10 | 0.07 | 0.05 | 0.19 | 0.10 | 0.07 | 0.13 | 0.06 | 0.06 | 0.06 | 0.11 | 0.10 | 0.12 | 0.16 | 0.08 | 0.11 | 0.10 | 0.04 | 0.05 | 0.18 |
| $X_7$ | 0.14 | 0.09 | 0.06 | 0.15 | 0.12 | 0.14 | 0.08 | 0.07 | 0.10 | 0.06 | 0.19 | 0.13 | 0.18 | 0.12 | 0.13 | 0.12 | 0.18 | 0.06 | 0.06 | 0.14 |
| $X_8$ | 0.11 | 0.10 | 0.07 | 0.18 | 0.11 | 0.08 | 0.14 | 0.05 | 0.07 | 0.07 | 0.15 | 0.16 | 0.12 | 0.11 | 0.09 | 0.12 | 0.11 | 0.09 | 0.06 | 0.13 |
| $X_9$ | 0.20 | 0.12 | 0.08 | 0.25 | 0.19 | 0.18 | 0.12 | 0.11 | 0.07 | 0.07 | 0.21 | 0.19 | 0.24 | 0.16 | 0.17 | 0.15 | 0.21 | 0.06 | 0.07 | 0.18 |
| $X_{10}$ | 0.14 | 0.19 | 0.11 | 0.18 | 0.15 | 0.13 | 0.11 | 0.08 | 0.10 | 0.06 | 0.22 | 0.15 | 0.21 | 0.19 | 0.19 | 0.15 | 0.21 | 0.06 | 0.08 | 0.17 |
| $X_{11}$ | 0.21 | 0.19 | 0.16 | 0.25 | 0.22 | 0.15 | 0.18 | 0.09 | 0.10 | 0.08 | 0.18 | 0.18 | 0.24 | 0.18 | 0.21 | 0.23 | 0.24 | 0.07 | 0.07 | 0.27 |
| $X_{12}$ | 0.24 | 0.14 | 0.10 | 0.26 | 0.20 | 0.13 | 0.16 | 0.14 | 0.16 | 0.13 | 0.24 | 0.14 | 0.27 | 0.18 | 0.18 | 0.23 | 0.22 | 0.07 | 0.11 | 0.24 |
| $X_{13}$ | 0.17 | 0.19 | 0.11 | 0.26 | 0.19 | 0.17 | 0.13 | 0.08 | 0.09 | 0.07 | 0.24 | 0.14 | 0.16 | 0.20 | 0.19 | 0.16 | 0.20 | 0.07 | 0.07 | 0.26 |
| $X_{14}$ | 0.12 | 0.08 | 0.06 | 0.21 | 0.19 | 0.14 | 0.12 | 0.07 | 0.07 | 0.06 | 0.12 | 0.10 | 0.13 | 0.11 | 0.12 | 0.19 | 0.10 | 0.05 | 0.04 | 0.21 |
| $X_{15}$ | 0.14 | 0.11 | 0.08 | 0.13 | 0.11 | 0.08 | 0.11 | 0.06 | 0.06 | 0.06 | 0.20 | 0.12 | 0.19 | 0.11 | 0.09 | 0.11 | 0.18 | 0.05 | 0.05 | 0.16 |
| $X_{16}$ | 0.08 | 0.06 | 0.05 | 0.16 | 0.14 | 0.06 | 0.10 | 0.05 | 0.05 | 0.04 | 0.09 | 0.08 | 0.09 | 0.12 | 0.06 | 0.08 | 0.07 | 0.04 | 0.03 | 0.15 |
| $X_{17}$ | 0.08 | 0.12 | 0.06 | 0.10 | 0.08 | 0.06 | 0.06 | 0.04 | 0.04 | 0.04 | 0.17 | 0.08 | 0.14 | 0.08 | 0.07 | 0.09 | 0.08 | 0.04 | 0.05 | 0.10 |
| $X_{18}$ | 0.20 | 0.17 | 0.10 | 0.25 | 0.20 | 0.13 | 0.15 | 0.13 | 0.13 | 0.14 | 0.19 | 0.20 | 0.22 | 0.20 | 0.15 | 0.18 | 0.18 | 0.06 | 0.15 | 0.23 |
| $X_{19}$ | 0.18 | 0.13 | 0.10 | 0.20 | 0.15 | 0.12 | 0.12 | 0.10 | 0.09 | 0.14 | 0.18 | 0.17 | 0.21 | 0.21 | 0.17 | 0.20 | 0.20 | 0.07 | 0.06 | 0.20 |
| $X_{20}$ | 0.19 | 0.15 | 0.08 | 0.26 | 0.23 | 0.11 | 0.12 | 0.13 | 0.13 | 0.07 | 0.21 | 0.18 | 0.23 | 0.20 | 0.12 | 0.22 | 0.15 | 0.06 | 0.07 | 0.17 |

*4.2. Determination of Influence Degree and Influenced Degree, Centrality Degree and Cause Degree*

Determine the influence degree $f_i$, the influenced degree $e_i$, the centrality degree $m_i$, and the cause degree $n_i$ of each influencing factor in the comprehensive influence matrix by Formulas (3)–(6) and sort out the indicators to obtain the DEMATEL analysis results of the influencing factors in Table 4.

**Table 4.** Results of DEMATEL analysis of influencing factors.

| Number | Influencing Factor | Influence Degree $f_i$ | Influenced Degree $e_i$ | Centrality Degree $m_i$ | Centrality Degree Ranking | Cause Degree $n_i$ | Factor Attribute |
|---|---|---|---|---|---|---|---|
| $X_1$ | Construction site selection | 3.578 | 3.166 | 6.744 | 5 | 0.411 | C |
| $X_2$ | Traffic and grid-connected state | 2.611 | 2.403 | 5.014 | 9 | 0.208 | C |
| $X_3$ | Survey and detection | 1.611 | 1.602 | 3.213 | 20 | 0.009 | C |
| $X_4$ | Cost of land use | 3.133 | 3.993 | 7.126 | 1 | −0.859 | R |
| $X_5$ | Financing conditions and loan methods | 2.564 | 3.204 | 5.768 | 7 | −0.640 | R |
| $X_6$ | Equipment procurement management | 1.927 | 2.276 | 4.203 | 18 | −0.349 | R |
| $X_7$ | Design scheme of photovoltaic power station | 2.323 | 2.430 | 4.753 | 13 | −0.107 | R |
| $X_8$ | Layout of battery assembly and mounting method of bracket | 2.126 | 1.617 | 3.743 | 19 | 0.508 | C |
| $X_9$ | Depth of design | 3.015 | 1.730 | 4.745 | 14 | 1.285 | C |
| $X_{10}$ | Light available hours | 2.866 | 1.505 | 4.371 | 17 | 1.361 | C |
| $X_{11}$ | Bidding and contract management | 3.490 | 3.630 | 7.120 | 2 | −0.141 | R |
| $X_{12}$ | Site construction management | 3.503 | 2.798 | 6.301 | 6 | 0.705 | C |
| $X_{13}$ | Construction machinery management | 3.155 | 3.698 | 6.853 | 4 | −0.542 | R |
| $X_{14}$ | Construction schedule management | 2.287 | 3.320 | 5.607 | 8 | −1.033 | R |
| $X_{15}$ | Project scale | 2.208 | 2.680 | 4.888 | 11 | −0.472 | R |
| $X_{16}$ | Power transmission and storage | 1.627 | 3.282 | 4.909 | 10 | −1.654 | R |
| $X_{17}$ | Repair and maintenance of equipment | 1.577 | 3.246 | 4.823 | 12 | −1.669 | R |
| $X_{18}$ | National policies and standards | 3.349 | 1.194 | 4.543 | 15 | 2.155 | C |
| $X_{19}$ | Market changes | 3.002 | 1.416 | 4.418 | 16 | 1.586 | C |
| $X_{20}$ | Natural environment factors | 3.087 | 3.850 | 6.937 | 3 | −0.763 | R |

C represents cause factor and R represents result factor.

In order to distinguish the cause and result attributes of each factor more clearly, a Cartesian coordinate system with centrality as the horizontal axis and cause degree as the vertical axis is established. The coordinate system is divided into four quadrants and the key factors are obtained with a high degree of cause and centrality. According to the sorting results of centrality, Excel is used to draw a scatter diagram, as shown in Figure 1. Causality is an important index to divide the attributes of factors. The factors with a causal degree greater than zero are divided into cause factors and those with a causal degree less than zero are divided into result factors, and 11 result factors and 9 cause factors are obtained. Centrality is an index reflecting the importance of factors, among which $X_4$ survey and detection is the factor with the highest centrality, indicating that it is the most important factor and should be paid full attention to.

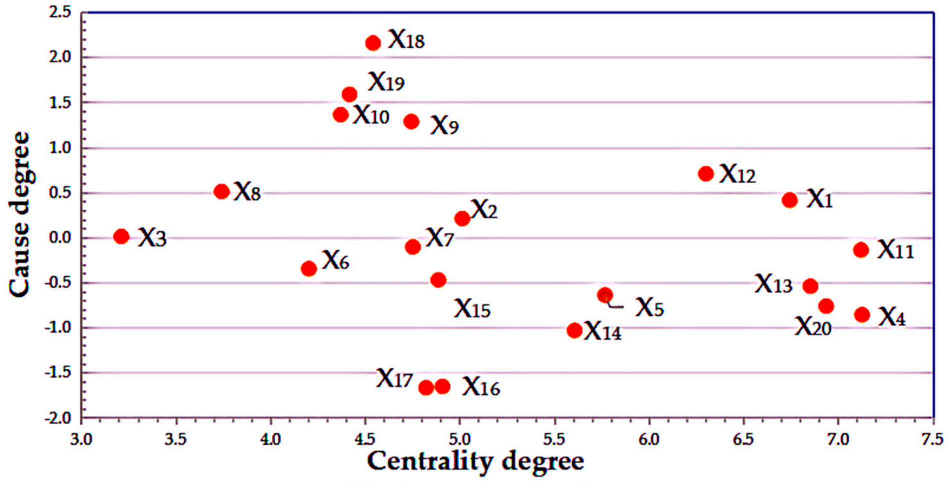


**Figure 1.** Cartesian coordinates of cause degree—centrality degree.

### *4.3. Determination of Reachability Matrix K*

Calculate the mean value and standard deviation of all elements in the comprehensive influence matrix, where the mean value is 0.12 and the standard deviation is 0.06. Considering the results of hierarchical division and the actual situation, $\lambda$ is 0.12. Thus, the reachability matrix $K$ is obtained, as shown in Table 5.

**Table 5.** Reachability matrix K of influencing factors.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{15}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $X_{19}$ | $X_{20}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| $X_2$ | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| $X_3$ | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $X_4$ | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| $X_5$ | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| $X_6$ | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $X_7$ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $X_8$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $X_9$ | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| $X_{10}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| $X_{11}$ | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| $X_{12}$ | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| $X_{13}$ | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| $X_{14}$ | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| $X_{15}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| $X_{16}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| $X_{17}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| $X_{18}$ | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| $X_{19}$ | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| $X_{20}$ | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |

### *4.4. Build a Multi-Order Recursive Interpretation Structure Model*

A multi-level recursive interpretation structure model can fully show the hierarchical structure and action path between factors. The model consists of eight factors, of which the bottom factor is the fundamental factor and plays a decisive role, the top factor is the direct factor, and the rest factors influence the top factor through the intermediate transition path. Based on the reachability matrix $K$, according to the extraction rule of result priority (UP type), hierarchical processing is carried out, and the final hierarchical division result is shown in Table 6.

**Table 6.** Hierarchical division.

| Hierarchy | Set of Factors | Hierarchical Description |
|---|---|---|
| $L_1$ | 16, 17 | Shallow factors |
| $L_2$ | 4, 5, 15, 20 | Shallow factors |
| $L_3$ | 6, 7 | Transitional factors |
| $L_4$ | 11, 13, 14 | Transitional factors |
| $L_5$ | 1, 2, 8 | Transitional factors |
| $L_6$ | 3, 9, 12, 10 | Deep factors |
| $L_7$ | 19 | Deep factors |
| $L_8$ | 18 | Deep factors |

Combined with the reachability matrix *K*, a multi-level recursive interpretation structure model is drawn, as shown in Figure 2.

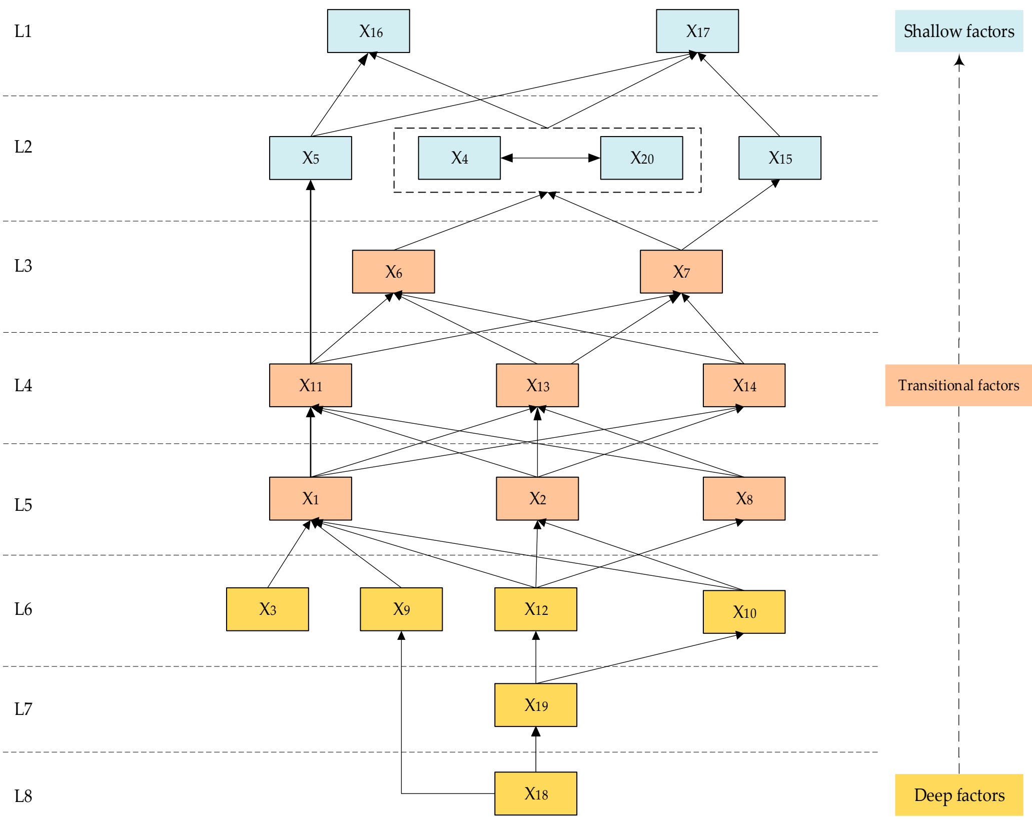


**Figure 2.** Multi-level recursive explanation structure model of influencing factors of centralized photovoltaic power generation project cost control.

## 5. Results and Suggestions

### *5.1. DEMATEL Analysis*

1. Analysis of influence degree and influenced degree:

As can be seen from Table 4, the factors with the highest degree of influence are $X_1$, $X_{12}$, $X_{11}$, $X_{18}$, and $X_{13}$, respectively. The factors with the highest degree of influenced are $X_4$, $X_{20}$, $X_{13}$, $X_{11}$, and $X_{14}$, respectively. There are overlapping areas, namely $X_{13}$ and $X_{11}$, indicating that these two items can not only affect other factors but can also be affected by other factors. In addition to these two factors, $X_1$, $X_{12}$, and $X_{18}$ are the three factors with higher ranking in the influence degree, and they are the root causes of centralized photovoltaic power generation cost control. The difference in construction site selection has a great impact on the project construction and operation and maintenance costs and has a significant impact on the input and output. Unreasonable site selection (such as poor photovoltaic resources, environmental obstructions, serious air dust, etc.) will cause the power generation to fail to reach the expected target, resulting in a sharp increase in maintenance costs. The level of site construction management determines the construction progress and quality. Because the site involves many working teams and different types of work, it is inevitable that the working surfaces will cross the construction site. The site management personnel will find and solve all kinds of unexpected problems in time to avoid the slowdown of personnel and idle equipment so that the construction can proceed smoothly. Because photovoltaic power generation technology is still in the initial stage of development, there is a lack of special system norms and technical standards in design and construction, and the design is based on the general standards of the power industry, which will lead to the risk of modification and change in the subsequent construction, and which will hinder the progress and quality of construction management.

$X_4$, $X_{20}$, and $X_{14}$ are the three factors with higher ranking among the influenced degrees, and survey and detection, natural environment factors, and construction machinery management are the direct factors of centralized photovoltaic power generation project cost control. The management of construction machinery and equipment is a key part of the whole process of photovoltaic power generation project construction. Mechanical equipment has the characteristics of large investment, various types and large quantities, and difficult transportation. The negligence of on-site management means and contents will lead to disorderly on-site management, neglect of the safety responsibility system by personnel, lax safety control of equipment, and inadequate maintenance of equipment, which will also directly lead to the increase in construction costs.

2. Analysis of Centrality and Causality:

As can be seen from Table 4, the top five factors of centrality are $X_4$, $X_{11}$, $X_{20}$, $X_{13}$, and $X_1$, respectively. The greater the centrality, the stronger the driving force of the influencing factors on the cost. The above five factors can play a significant role in the cost control of centralized photovoltaic power generation projects. The local geological and hydrological conditions were investigated, and it was determined whether it has corrosive or other destructive effects on the foundation and support of the proposed power station. Perfecting the details, setting the contract terms in the bidding process, and controlling the cost of the whole process from bidding evaluation to winning the bid are the key points of the owner's cost control work. At the same time, perfecting the restraint system for the general contractor when signing the contract can greatly avoid various subsequent cost risks. The natural environment has a great influence on the operation and maintenance of centralized photovoltaic power generation. Different weather conditions have different operation and maintenance costs, and high-intensity maintenance is needed in case of severe weather such as gale, rain, and snow. Reasonable construction schedule control can reduce costs and increase project competitiveness by reducing labour and financial costs and advancing the construction period. Considering the balance between construction site selection and cost, technical and economic analysis of multiple schemes is needed to determine the best site selection scheme.

Combined with Figure 1, it can be seen that the order of causes is $X_{18}$, $X_{19}$, $X_{10}$, $X_9$, $X_{12}$, $X_8$, $X_1$, $X_2$, and $X_3$, among which the top five causes are national policies and standards, market changes, light available hours, design depth, and site construction management, which have a great influence on cost control and are basically consistent with the hierarchical treatment results obtained by ISM. In particular, $X_{18}$ is the highest-ranking factor, so we should focus on the release, adjustment, and changes of relevant national policies and industry standards in cost control. Results factors according to the degree of causes, ranked as $X_7$, $X_{11}$, $X_6$, $X_{15}$, $X_{13}$, $X_{20}$, $X_{14}$, $X_{16}$, $X_{17}$, $X_5$, and $X_4$, among which the top five factors are photovoltaic power plant design scheme, bidding and contract management, equipment procurement management, project scale, and construction progress control, are easily interfered by other factors, have a direct impact on cost control, and are distributed throughout the project. The design scheme of the photovoltaic power station is to determine the design framework in the decision-making stage and design stage, continuously optimize the software and hardware design, compare and select multiple schemes in combination with technical and economic conditions, and choose the best design scheme to reduce the cost. The bidding process is an important link to reflect the needs of the owner and the ability of the construction party. When signing a contract, we should consider the possible risks in the future as much as possible and formulate specific contract terms on various issues to ensure the rationality, compliance, and legality of the bidding process. At the same time, the principle of attaching importance to the unit price based on the total price is adopted to evaluate the rationality and reliability of the quotation composition and avoid unnecessary claims in the future. Equipment procurement management adopts centralized procurement in most cases of centralized photovoltaic power generation projects, which will involve bidding. A perfect bidding mechanism can not only ensure the quality of equipment and construction progress but also greatly save money.

### *5.2. ISM Analysis*

According to the hierarchical relationship between influencing factors presented in Figure 2, the analysis results are as follows:

1. L8, L7, and L6 are the deep factors that affect the cost control of centralized photovoltaic power generation. The deep factors have the characteristics of impressing other factors, which are located at the bottom of the topology diagram and only send upward-directed line segments, including the six factors of $X_3$, $X_9$, $X_{10}$, $X_{12}$, $X_{18}$, and $X_{19}$. $X_3$ belongs to the transition factor, and although it is in the position of L6, there is no other antecedent factor pointing to it. Among these six factors, except for uncontrollable factors, most of the other factors are in the project decision-making stage and will have a lasting impact on the subsequent project construction. For example, the nature of the land will affect whether the project can be established, and the ownership of land property and landform characteristics will affect the difficulty of land acquisition and subsequent construction. The design depth will affect the construction scheme, equipment selection, etc., and will also cause a number of subsequent design changes, and control the cost in the pre-stage. On-site construction management is the embodiment of multiple factors such as the management level of managers, the advantages and disadvantages of construction organization design, and the rationality of schedule control, which will have an impact on quality, safety, schedule, and cost. Policies, standards, and market changes are two invisible hands. Through policy guidance, we can improve the development of the industrial chain, standardize industry standards, regulate market demand, and finally affect specific projects.
2. L5, L4, and L3 are the transitional factors that affect the cost control of centralized photovoltaic power generation. The remarkable feature of this layer factor is that it cannot only influence other factors but can also be influenced by other factors. It spans three levels and has eight factors, including $X_1$, $X_2$, $X_6$, $X_7$, $X_8$, $X_{11}$, $X_{13}$, and $X_{14}$. These eight factors are the core influencing factors of centralized photovoltaic power generation project cost control, which are influenced by deep factors and play a bridging role in the whole life cycle of the project. Construction site selection, transportation, and grid-connected status belong to the decision-making stage. These two factors will be limited by national policies, the overall layout, and macro-control of the country, but they will also have an impact on the power generation capacity of the project, the difficulty in transportation, and the cost of grid connection. Equipment procurement management, the design scheme of the photovoltaic power station, bidding, and contract management belong to the design stage. These factors are not only influenced by the natural conditions of the construction site, construction progress control, and construction machinery management in the early stage of site selection but also belong to the construction stage. As a stage that lasts for a long time and produces the largest proportion of costs in the whole project construction process, reasonable construction progress control is not only a guarantee for the project to be completed on schedule but also can effectively control the direct costs

of labour, materials, and machinery. The construction of a centralized photovoltaic power generation project needs to use many large-scale machineries, and the lease or purchase of these machineries, the arrangement of entry and exit time, the division of working face, etc., all need to be considered during construction.

3. L2 and L1 are shallow factors that affect the cost control of centralized photovoltaic power generation. It is the characteristic of shallow factors that only accept the influence of other factors without affecting other factors. The factor set of this layer includes $X_4$, $X_5$, $X_{15}$, $X_{16}$, $X_{17}$, and $X_{20}$. Except for the project scale and natural environment, the other factors are directly or indirectly related to the site, which belong to the direct or indirect carrier of the cost and are closely related to the actual cost. As direct causes, they affect the cost control of centralized photovoltaic power generation projects and have a direct role in promoting cost reduction. The larger the scale of the project, the greater the installed capacity, floor space, etc., and the greater the direct cost. Natural environmental factors such as rain and snow will directly affect the smooth progress of construction and the cost of operation and maintenance.

### *5.3. DEMATEL-ISM Analysis*

Combined with the ranking results of the centrality of each factor obtained by DEMATEL analysis and the hierarchical relationship presented by the multi-order recursive explanatory structure model, the following conclusions can be drawn:

1. There is no obvious correlation between centrality and hierarchical division. As the calculation of centrality is based on the sum of the factors' own influence degree and the influenced degree, as long as there are enough influencing factors, they may rank high, while the hierarchy division is based on the transmission order of influence, focusing on the judgment of causality, so the centrality of deep factors may not be high.
2. There is a certain correlation between the degree of causation and hierarchical division. The calculation of cause degree reflects the extent to which this factor can influence or be influenced by other factors, which is consistent with the hierarchical division logic of the multi-level recursive interpretation structure model. Among them, the higher the ranking of the cause degree of the cause factors, the lower the hierarchical position; the higher the ranking of the cause degree of the result factors, the higher the hierarchical position.
3. The comprehensive results show that national policies and standards have the highest degree of cause among the causes analysed by DEMATEL, which are the most critical factors and correspond to the deepest influencing factors in ISM analysis. Among the factors affecting the transition layer, bidding and contract management have the highest degree of centrality and are the most important factors. In the shallow influencing factors layer, transmission and storage of electricity and equipment repair and maintenance are the most direct factors affecting cost control, and they are also effective ways to control the cost of centralized photovoltaic power generation projects. Paying attention to direct factors is more effective in cost control.

### *5.4. Measures and Suggestions*

1. Increase policy support and improve industry standards.

National policies and standards are the deepest influencing factors. The guidance of the government will be conducive to standardizing the healthy development of the industry in accordance with the principles of fairness and rationality. The central government first formulates macro industrial policies that conform to the laws of China's industrial development according to the national economic development strategy and planning and the objective social environment, and then introduces local governments that conform to local conditions to play a role in the local photovoltaic market. For example, in view of the land use procedures for centralized photovoltaic power generation projects, land use supervision should be strengthened while ensuring the smoothness of land acquisition and reducing investment costs. Businesses should adhere to the principle of the market mechanism leading and government optimizing services, optimize the business environment, and stimulate the scientific research enthusiasm of enterprises and professionals based on preferential policies such as tax reduction, tax rebate, and R&D fund subsidy for photovoltaic enterprises to help enterprises promote the development of power technology. Under the background of industry expansion, the government should introduce policies to promote the development of economies of scale, promote the reduction in technology-driven costs and the downward resonance of localization-guided prices, strengthen the cooperation between upstream and downstream enterprises, relieve the upstream and downstream production capacity and price congestion in the industrial chain, and enhance the supporting supply guarantee capacity of the supply chain. The government should also establish unified industry standards, improve product quality, and reduce market competition costs. For the grid-connected link of centralized photovoltaic power generation, the management requirements of key joints of grid-connected photovoltaic power generation projects are clarified, the responsibility of power grid enterprises is implemented, the coordinated development of network and source is strengthened, and power transportation is guaranteed.

2. Macro-control of the market and micro-exploration of the law.

Market changes are the most important root factors besides national policies and standards. From a macro perspective, the construction of a large number of photovoltaic power plants makes the market of photovoltaic products rise, promotes the reform of electricity marketization, and makes the photovoltaic power generation industry more active and transparent. Enterprises rely on the market to give full play to their own advantages, expand market scale and investment, and accelerate technological innovation and product promotion. Achieving healthy competition and gradually rationalizing the price of photovoltaic products can not only reduce the use cost of project construction but also increase the use space of products. The market supervision department should also strictly supervise the building materials market to ensure the transparency of material price information. From the micro level, the cost of main equipment and materials accounts for more than 70% of the project investment, and it is easily affected by the external environment. The construction unit can dynamically grasp the market situation by establishing an information system. The construction unit should set up an information reporting department to find out the price information of the required materials, equipment, and other resources from the completed projects, strengthen the storage and collation of the information of the main materials and equipment, keep abreast of the domestic and international construction market, and scientifically predict the overall trend of the main materials price. It should also arrange the purchasing organization to coordinate with the material suppliers when purchasing and find a number of suppliers for price comparison if necessary, so as to ensure orderly construction and avoid the adverse impact on the cost caused by price changes.

3. Standardize the bidding process and improve the contract.

Bidding and contract management are the most important factors in the transition. The winning bid determined by bidding is the basis of the contract price and plays a decisive role in the cost. When issuing the bid, we should try our best to ensure the completeness of the bill of quantities and the rationality of the measurement method. We should pay attention to reviewing the construction plans provided by various construction units when clearing the bid, and compare the differences in unit prices of listed items caused by different construction technologies and construction organization plans. The bidder shall be informed in time if there are errors in the calculation of quantities or missing items in the quotation, so as to avoid subsequent disagreement on the composition of the quotation. In bid evaluation, the principle of attaching importance to unit price based on total price is adopted to prevent and limit unbalanced quotation. Finally, when signing the contract, negotiate the contents of possible disputes and formulate solutions and measures. The state and government should do a good job in strict examination and management, improve the imperfect bidding management system and supervision system, and avoid vicious competition among bidding enterprises. Contract management involves the whole process from decision-making, design, and construction to operation and maintenance. All departments should meet the needs of contract management at all stages of bidding. A contract ledger registration management system should be established, and the contract performance should be strictly reviewed during the construction process to check the construction situation at each stage to avoid disputes and changes.

4. Control transmission investment and reduce operation and maintenance costs.

Transmission and storage of electricity and equipment repair and maintenance are the most direct factors affecting cost control, and they are also effective ways to control the cost of centralized photovoltaic power generation projects. Transmission has always been under pressure to reduce costs, which include initial investment and operation and maintenance costs. The initial investment cost reflects the fixed investment cost of construction lines, transmission equipment, etc., while the operation and maintenance costs reflect the variable cost that constantly changes with the system operation. In addition to the analysis of the cost of components, brackets, inverters, and other equipment, we should also pay attention to the construction cost of power stations. When building a large tower, expensive assembly and transportation costs are often needed, while exploring automatic assembly may realize more complicated transmission tower assembly at a lower cost. Choosing appropriate cable specifications and reasonably arranging the location of electrical equipment can save the material cost of the photovoltaic power station. Considering the centralized placement of series inverters, the line loss can be minimized and the cost in the construction and operation and maintenance stages can be reduced. According to factors such as load capacity, power supply distance, and power grid distribution, designers should choose appropriate power supply voltage, and reduce some transformers according to load conditions to reduce line loss. The operation and maintenance management of equipment should make a scientific operation plan and management scheme, and making a reasonable power generation plan according to the resource endowment of the construction area is also conducive to improving power generation efficiency and reducing operating costs. In order to save costs better, it is suggested to carry out refined management. First of all, the operation and maintenance department of the power station should shoulder the responsibility of operation and maintenance management, formulate a detailed management and maintenance plan for photovoltaic power stations, establish equipment information file ledger management, set different inspection cycles for different types of equipment, carry out different levels of maintenance measures such as daily maintenance, regular maintenance and power station downtime maintenance, and supervise the completion of actual maintenance and maintenance. Spare parts should be purchased according to the statistical analysis of the damage rate and replacement rate in actual work, so as to avoid inventory pressure or cost waste. In addition, it is necessary to strengthen the cultural construction of equipment operation and maintenance management, cultivate managers' ideology of "Every kilowatt hour counts.", and guide daily work with refined management methods.

## 6. Conclusions

Photovoltaic power generation project, as a clean and environmentally friendly renewable energy project, has obvious social and economic benefits, and so it has become one of the rapidly developing energy industries. With the large scale of centralized photovoltaic construction, there are many factors influencing the cost control in the whole life cycle, and there are still few studies on the cost management of centralized photovoltaic power generation projects. From the perspective of sustainable development of the industry, it is necessary to study the cost management of centralized photovoltaic power generation projects. In this paper, the influencing factors of cost control of centralized photovoltaic power generation projects are studied, and the main conclusions are as follows:

(1) Starting from the decision-making stage, design stage, construction stage and operation and maintenance stage that affect the cost control of centralized photovoltaic

power generation project, this paper identifies 20 influencing factors from controllable factors and uncontrollable factors, constructs an index system of influencing factors of centralized photovoltaic power generation project cost control, analyses the correlation between influencing factors by using the method of DEMATEL-ISM, and constructs a multi-order recursive explanation structure model. Based on this, the nature and importance of each factor is determined by the analysis of DEMATEL results. From ISM analysis, the action path between various factors is presented, and the causes of the shallow layer, transition layer, and deep layer are determined. Finally, the factors with the highest degree of importance in each level are determined by combining the two parts, and it is proposed that we should focus on these factors.

(2) Among the influencing factors of centralized photovoltaic power generation project cost control, national policies and standards are the deepest influencing factors, with the highest degree of reason, which is 2.155; the reason degree of market changes is the second, which is 1.586; bidding and contract management are the factors with the highest centrality, which is 7.120; and transmission and storage of electricity, equipment repair, and maintenance are the most superficial positions in the whole multi-level recursive interpretation structural model, which are the most direct factors affecting cost control.

(3) Based on the analysis results and discussions, the following inspirations are drawn: Firstly, we should strengthen the fundamental key factors, continuously strengthen policy guidance, and improve industry standards. The second is to implement the intermediate factors, strictly supervise the bidding management of materials and equipment, and ensure the fairness of competition. Finally, we should pay attention to the cost of operation and maintenance, coordinate the power demand and power generation plan, and formulate a refined management system for equipment maintenance.

The research in this paper can provide a decision-making reference for project investors, government departments, construction units, and other stakeholders, help them understand the influencing factors of centralized photovoltaic power generation project cost control, and sort out the relationship between the influencing factors. Due to the complexity of questionnaire data and the limitation of survey time and objects, the number, extensiveness, and accuracy of the questionnaire survey need to be strengthened. The research object of this paper is mainly aimed at the project construction unit, construction unit, and design unit, and the understanding of upstream and downstream enterprises, supervision units, and equipment suppliers is still insufficient, which cannot accurately reflect the action path of each participant in the industrial chain to the cost. There is no detailed analysis of the impact of micro-cost composition on the final cost, so we can establish an economic calculation model from the perspective of economics and conduct a sensitivity analysis of a single factor or multi-factors. From the perspective of theoretical research, follow-up research can start from the perspective of risk control, from the perspective of risk source, risk process, and risk result, and further control the cost of centralized photovoltaic power generation projects.

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