

Hierarchical management of power grid material suppliers based on analytic hierarchy process

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Abstract. There are many features in the process of electricity infrastructure, such as large investment, complex technology and various materials. Whether procurement can meet the economic, qualified and timely supplies and other requirements of electricity companies, it exerts a significant impact on the operation stability and costs reducing of power grid enterprises. Combining with the characteristics of the South Power Grid Corp supplier management, in this paper, the theory and method of supplier classification object group selection, model establishment and supplier relationship management are described; a hierarchical model of grid material supplier is constructed, and the corresponding management strategies are put forward according to the classification results.

Keywords: analytic hierarchy process, power grid material, suppliers management system, comprehensive evaluation

1 Introduction

Procurement cost as one of the largest operating costs in an enterprise is an important concern of enterprise managers. At this stage, power Grid Company just has checked the suppliers' access certificates. In selecting partner suppliers, power companies only have a rough estimation of the suppliers overall strength through bidding documents, When confronted with a plurality of viable suppliers; it is completely determined by the subjective evaluators, which affects the science and equity procurement. Weber^[6] had reviewed 74 documents with supplier selection which published from 1966, focused on the supplier selection process of 23 guidelines, related to the quality, delivery, price and attitude; he also provided the JIT effect in supplier selection analysis.

According to excellent evaluation method of enterprises, Johnson^[8] molding the case study the from four aspects, such as the proposed strategy, culture, processes, technology of potential suppliers, and according to the characteristics of the relationship between the supplier in accordance with the 17 key points from the range of options available to the supplier selection method.

Yahya and Kingsman^[11] used Analytic Hierarchy Process to obtain the vendor evaluation criteria and corresponding weights that supplier evaluation factor of importance is in order of delivery, quality, facilities, technical capabilities, financial status, management, discipline and response^[11]. Tan Tracey believes that supplier selection is based on commitment, demand, capacity, fit and integrity, and establishes a supplier evaluation system based on delivery, quality, speed and information sharing^[9]. Demirtas and Ustun point out from four levels of interest, opportunity, cost and risk in the purchase decision-making research, and have 14 standards to measure the supplier, and use the two stage evaluation to choose the supplier^[5].

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In the process of China Southern Power Grid in an effort to regulate the internal management of enterprises, improve work efficiency, complete world-class enterprise management objectives, the enterprise managers dedicate to improve and standardize the internal control and external control measures. In accordance with the relevant laws of the Power Grid Corp and regulations of the internal system for the power grid enterprises, public bidding is the main method for the materials procurement. At the same time, the power grid construction project is in the form of the operation of the project. In order to obtain the maximum cost savings through bidding, Power Grid Corp has a lot of supplier resources. Although the supplier resources have certain stability in the long term, but with the specific suppliers cannot maintain a continuous and stable cooperation.

Therefore, power grid enterprise material supplier evaluation task is not make choice of final supplier, but for helping the bidding and purchasing in the final supplier selection. Which is different the manufacturing enterprises trying to select different suppliers through the supplier evaluation index system. At this stage, qualification reviewing is the only access of the Power Grid Corp in the choice of a cooperative supplier. It is only a rough estimate of the overall strength of the supplier through the tender documents. When confronted with multiple feasible suppliers, it is entirely subjective, which affects the scientific and fairness of the procurement. Aiming at this problem, this paper discusses the characteristics of power grid enterprises on the evaluation of power grid material suppliers. Southern Power Grid Corp has established a preliminary supplier relationship management system, including supplier registration, supplier qualification capability verification, supplier performance evaluation, supplier's bad behavior treatment and so on. To deal with a large number of suppliers, which have different influence on category, quantity, it is necessary to grading the management of suppliers. Base on performance evaluation results of a comprehensive evaluation of the existing supplier in the Southern Power Grid Corp, they would be divided into 4A, 3A, 2A, class A. According to the classification results, the corresponding management strategy would be given.

2 Grading process

2.1 Determining the objects to be graded

After verifying the ability and qualification of the suppliers, they shall be classified in the Southern Grid Company e-commerce registration system; they should be divided into two categories of cooperative suppliers and new suppliers.

2.2 Establishing of grading evaluation index system

Making use of the China Southern Power Grid Company existing supplier management achievements and e-commerce platform vendor data, through quantitative competence indicators and performance evaluation index, we can construct the China Southern power grid material supplier evaluation index system of classification.

Qualification ability index mainly inspects the vendor's own strength and quality of products; evaluation basis of supplier registered in the electronic commerce platform (ECP) provided data; performance evaluation mainly inspects the supplier in the contract, after-sales service, quality control and product quality performance situation, the evaluation results directly from scores of the performance evaluation. To suppliers, which have been built relationship, the comprehensive quality ability and performance evaluation is the two aspects of evaluation.

During the analysis process, Analytic Hierarchy Process (AHP) is suggested as a classification application tool. AHP is a decision method combining qualitative analysis and quantitative analysis, the basic principle is taking the decision problem as a system of a variety of effects, through the analysis of a large system the influence factors and the relationship, and in accordance with the subordination relationship formed from high to low arrangement of a multi-level structure. At the second, the experts, scholars, authorities, referring the importance of each level of the two-two factors; calculate the weight of each factor, then provide the basis for the choice of the best program. AHP is applied to select the weight of evaluation factors in supplier evaluation, so as to calculate the evaluation results of the supplier.

2.3 Basic procedures of ahp

2.3.1 Establish hierarchical structure

The first step to solve the problem by using the analytic hierarchy process is to establish the hierarchical structure model. This is based on decision makers' full understanding of the goal, the problem and the program. Generally, it can be divided into three types:

- (1) The highest level: it is also known as the top layer, the target layer, contains only one element, which is the total target of the decision analysis.
- (2) The middle layer: contains a number of layer elements, which means the various sub objectives involved in the implementation of the general objectives, including a variety of criteria, constraints, strategies, etc. Therefore, it is also known as the standard layer.
- (3) The lowest level: the implementation of the decision-making objectives of the feasible solutions, measures, etc. it is also known as the program layer, the measure layer.

The typical hierarchical structure is as follow:

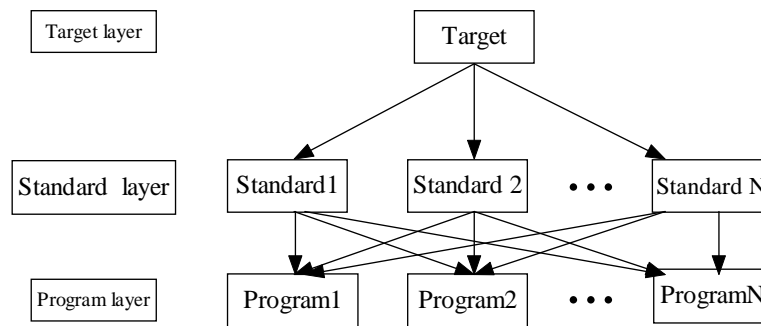


Fig. 1: Structure of analytic hierarchy process

2.3.2 Establishing judgment matrix

After finishing the establishment of a hierarchical structure, the ordering weight of the lower elements dominated of every upper layer element is required. Building a matrix is a key step in the analytic hierarchy process.

The judgment matrix indicates the relative importance of each element in the hierarchy for a certain element in the upper level. With m goals (programs or elements), according to a certain criterion, the m two-two goals are compared, put a third goal in the $(i = 1, 2, \dots, m)$ the relative importance of the j to the first is denoted as $A_{ij}(j = 1, 2, \dots, M)$,

The structure of m order matrix is applied to solve the priority weight of a certain criterion, and it becomes the weight analytic judgment matrix, and the judgment matrix is abbreviated as.

The typical matrix is as follow:

$$A = \begin{bmatrix} \frac{a_1}{a_1} & \dots & \frac{a_1}{a_m} \\ \frac{a_1}{a_1} & \dots & \frac{a_1}{a_m} \\ \vdots & \ddots & \vdots \\ \frac{a_m}{a_1} & \dots & \frac{a_m}{a_m} \end{bmatrix} .$$

Satty in 1980, according to the general people's cognitive habits and ability to determine, establish the relative importance of the table (see Table 1). Using this table to take the value of A_{ij} , it is known as the 1-9 scale method.

Table 1: The value of the elements in the matrix A of the objective importance

Relative importance	Defined	Description
1	equal important	two a target also important
3	slightly important	by experience or evaluated factors, think the target is slightly important than another
5	quite important	by experience or evaluated factors, think the target is more important than another
7	obvious important	the target is more important than another, and the importance has been practice proved
9	absolutely important	the target is absolutely more important than another
2,4,6,8	Between the adjacent value index	Need to compare the importance of the two adjacent value index, and the result is in the between of the both.

2.3.3 Ordering and consistency checking of single criteria

The information foundation of analytic hierarchy process is the comparable judgment matrix. Each rule is governed by a number of factors, so we can get a comparable judgment matrix for each criterion and the factors which are controlled.

According to the comparison of how to determine the matrix of each factor W_1, W_2, \dots, W_m for the standard A, the relative weight of the process is called single criteria of the sort.

If the weight vector is taken, then there is an equation:

$$AW = \lambda W$$

λ is the maximum positive eigenvalue of A, so W is the characteristic vector which A corresponding to of λ .

In order to get the relative weight of this set We should transform hierarchical single ranking into the maximum eigenvalue λ_{\max} of the judgment matrix and the corresponding feature vectors.

In order to check the consistency of the judgment matrix, it is necessary to calculate the consistency of the matrix:

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

When $CI = 0$, the judgment matrix is completely consistent; conversely, the CI is bigger, the consistency of the judgment matrix is worse.

In order to check the consistency of the judgment matrix, the CI and the average random consistency index RI should be compared.

In general, when the following inequality is matched:

$$CR = \frac{CI}{RI} < 0.10$$

We consider that the judgment matrix has met consistency; when $CR \geq 0.10$, we need to adjust the judgment matrix until it be met.

2.3.4 Hierarchical total ordering and consistency checking

The important weight of the all elements in this layer can be calculated by using the result of single ranking of all levels in the same layer.

Hierarchical aggregate ordering needs to be carried out sequentially from top to bottom. For the highest level, the level of a single sort is its total order.

In order to evaluate the consistency of the calculation results of the hierarchical total ranking, similar to the hierarchical order, the consistency check is necessary.

$$CI = \sum_{j=1}^m a_j CI_j,$$

$$RI = \sum_{j=1}^m a_j RI_j,$$

$$CR = \frac{CI}{RI} < 0.10.$$

CI is the consistency index of the level of the total ranking, and is the consistency index of the judgment matrix of the corresponding to the B level; RI is the random consistency index of the level of the total ranking, and CI_j is the random consistency index of the judgment matrix of the α_j corresponding to the level B; CR is the random consistency of the total level sorting.

3 Case study

3.1 Supplier rating

AHP is in use of the calculation of the weight index system to evaluate a supplier, a large number of indicators are involved, and it is necessary to build a more comprehensive, complex index system.

The rate of each index to the total target is different, that is, the weight of each index is different, and the choice of the weight directly affects the final evaluation result.

As an example of 10 kV switch cabinet, through the feedback of public bidding and suppliers evaluation questionnaire, the final choices are six companies as the final evaluation of the evaluation object. Through the collection of expert opinion, and field materiel management staff on-site data recording, the suppliers' evaluation of original data is shown in Tab. 2.

Table 2: The raw data of the suppliers' performance of 10kV switch cabinet

Index layer	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
Rate of qualified products	0.965	0.881	0.866	0.951	0.869	0.962
Quality certification	96.56	87.56	93.33	85.22	90.00	86.00
Return and rework ratio	0.037	0.041	0.056	0.139	0.026	0.02
Delivery timely ratio	1.00	0.88	0.95	0.91	0.87	0.93
Meet the demand	0.968	0.896	0.957	0.873	0.936	0.883
Adapt to demand change	0.956	0.999	0.978	0.867	0.933	0.9
products price	1.919	1.922	1.909	1.929	1.913	1.92
management cost	0.054	0.102	0.083	0.091	0.062	0.076
Service commitments	95.6	91.33	94.89	83.56	91.44	92.56
Response after-sale	14.89	15.26	15.55	15.56	15.76	15.67
Complaints solution	0.876	0.796	0.892	0.79	0.853	0.821
Production capacity	86.56	89.67	92.89	90.33	94.67	91.11
Designing ability	88.44	92.33	96.5	89.8	94.7	90.2
Quick Ratio	1.033	1.111	1.367	1.211	0.987	1.1
Assets and liabilities	0.617	0.621	0.614	0.626	0.628	0.622
Asset turnover	0.181	0.183	0.174	0.169	0.166	0.174
The quality of staff	95.67	92.33	90.22	88.67	91.56	89
Staff degree	0.606	0.625	0.598	0.595	0.591	0.615
Research Investment	0.051	0.052	0.053	0.052	0.053	0.053
Period of cooperation	2.76	2.76	2.66	2.76	3.33	2.66
Contract fulfillment	0.97	0.88	0.96	0.91	0.92	0.80
Corporate culture compatible	95.33	91.22	96.56	98.67	94.67	90.11
Strategic concept compatible	88.56	90.67	91.22	94.33	95.55	93.56
Management system compatible	96.33	92.67	94.44	89.78	95.33	96.8

We should quantify the performance of the verification indicators, and use the analytic hierarchy process to calculate the weight of each index.

The relative importance of each index at the same level is compared with 9 two-two scale method, and the judgment matrix is obtained through the arrangement. For example for the target layer of the three indicators two-two compared to the following matrix:

$$A = \begin{bmatrix} 1 & 4 & 6 \\ 1/4 & 1 & 3 \\ 1/6 & 1/3 & 1 \end{bmatrix}$$

Because of the design matrix complexity, we use EXCEL for the matrix calculation for maximum eigenvectors and eigenvalues of matrix A as follows:

Table 3: Excel calculation table

No.	B	C	D	E	F	G	H	I
1	1	4	6	24	2.884499	0.691	2.1099	3.0536
2	1/4	1	3	0.75	0.90856	0.2176	0.6646	
3	1/6	1/3	1	1.0556	0.381571	0.0914	0.2791	

Setting the following formula:

- Taking B1-D3 as the judgment matrix, H1-H3 as the feature vector, I1 as the maximum eigenvalue;
- $E1 = C1 \times C1 \times C1$, Similarly $EZ = BZ \times CZ \times DZ$, and so on;
- $F1 = \text{POWER}(E1, 1/3)$, Similarly, $FZ = \text{POWER}(EZ, 1/3)$, $F3 = \text{POWER}(E3, 1/3)$;
- $G1 = F1/\text{SUM}(F1 : F3)$, Similarly, $GZ = F3/\text{SUM}(F1 : F3)$, $G3 = F3/\text{SUM}(F1 : F3)$;
- $H1 = \text{MMULI}(B1 : D1, G1 : G3)$, $H1 = \text{MMULI}(BZ : DZ, G1 : G3)$, $H1 = \text{MMULI}(B3 : D3, G1)$
- $I1 = ((H1/G1) + (G3); HZ/GZ) + (H3/G3))/3$.

The function POWER () is to return the value of the square root; function MMULT () is to return the product of the two array matrix, the function SUM () is to return the sum of all the values in the cell. After finding out the characteristic vector and the characteristic value, we can check the consistency of the matrix:

$$CI = \frac{\lambda_{\max} - n}{n - 1} = \frac{3.0536 - 3}{3 - 1} = 0.026811,$$

$$CR = \frac{CI}{RI} = \frac{0.026811}{0.58} = 0.046 < 0.10.$$

Therefore, the judgment matrix has good consistency.

For the target layer index, the relative weight of B1, B2 and B3 is 0.6910, 0.2176 and 0.0914. The relative weight of each index to the upper layer is obtained by the EXCEL method above.

The calculation results are summarized as follows:

Table 4: Target layer A judgment matrix table

A	B1	B2	B3	Weight	Consistency
B1	1	4	6	0.691	$\lambda_{\max} = 3.0563, CR = 0.046 < 0.1$
B2	1/4	1	3	0.2176	
B3	1/6	1/3	1	0.0914	

According to the above method can get the characteristic vector of all matrixes, the same can be obtained: In combination with the evaluation of raw data in table 2 and the weight of each index in Tab. 4–17, the final score of each supplier can be concluded as follows:

Table 5: Judgment matrix table of B1

B1	B11	B12	B13	B14	Weight	Consistency
B11	1	1	3	3	0.375	$\lambda_{\max} = 4, CR = 0 < 0.1$
B12	1	1	3	3	0.375	
B13	1/3	1/3	1	1	0.125	
B14	1/3	1/3	1	1	0.125	

Table 6: Judgment matrix table of B2

B2	B21	B22	B23	Weight	Consistency
B21	1	3	4	0.6250	$\lambda_{\max} = 3.0183, CR = 0.0158 < 0.1$
B22	1/3	1	2	0.2385	
B23	1/4	1/2	1	0.1365	

Table 7: Judgment matrix table of B3

B3	B31	B32	Weight	Consistency
B31	1	2	0.6667	$\lambda_{\max} = 2, CR = 0 < 0.1$
B32	1/2	1	0.3333	

Table 8: Judgment matrix table of B11

B11	C1	C2	C3	Weight	Consistency
C1	1	3	2	0.5396	$\lambda_{\max} = 3.01, CR = 0.016 < 0.1$
C2	1/3	1	1/2	0.1634	
C3	1/2	2	1	0.2970	

Table 9: Judgment matrix table of B12

B12	C4	C5	C6	Weight	Consistency
C4	1	2	5	0.5816	$\lambda_{\max} = 3, CR = 0 < 0.1$
C5	1/2	1	3	0.3090	
C6	1/5	1/3	1	0.1094	

Table 10: Judgment matrix table of B13

B13	C7	C8	Weight	Consistency
C7	1	2	0.6667	$\lambda_{\max} = 2, CR = 0 < 0.1$
C8	1/2	1	0.3333	

Table 11: Judgment matrix table of B14

B14	C9	C10	C11	Weight	Consistency
C9	1	1/2	3	0.3090	$\lambda_{\max} = 3, CR = 0 < 0.1$
C10	2	1	5	0.5816	
C11	1/3	1/5	1	0.1094	

Table 12: Judgment matrix table of B21

B21	C12	C13	C14	Weight	Consistency
C12	1	3	5	0.6483	$\lambda_{\max} = 3.004, CR = 0.003 < 0.1$
C13	1/3	1	2	0.2297	
C14	1/5	1/2	1	0.1220	

Table 13: Judgment matrix table of B22

B22	C15	C16	C17	Weight	Consistency
C15	1	1/2	1	0.5000	$\lambda_{\max} = 3, CR = 0 < 0.1$
C16	2	1	2	0.2500	
C17	1	1/2	1	0.2500	

Table 14: Judgment matrix table of B23

B23	C18	C19	Weight	Consistency
C18	1	1	0.5000	$\lambda_{\max} = 2, CR = 0 < 0.1$
C19	1	1	0.5000	

Table 15: Judgment matrix table of B23

B31	C20	C21	Weight	Consistency
C20	1	1/5	0.1667	$\lambda_{\max} = 2, CR = 0 < 0.1$
C21	5	1	0.8333	

Table 16: Judgment matrix table of B31

B31	C20	C21	Weight	Consistency
C20	1	1/5	0.1667	$\lambda_{\max} = 2, CR = 0 < 0.1$
C21	5	1	0.8333	

Table 17: Judgment matrix table of B32

B32	C22	C23	C24	Weight	Consistency
C22	1	2	4	0.5000	$\lambda_{\max} = 3, CR = 0 < 0.1$
C23	1/2	1	2	0.2500	
C24	1/4	1/2	1	0.2500	

Table 18: Final evaluation score of suppliers

NO.	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
Score	0.7756	0.7644	0.7652	0.6176	0.6304	0.6209

After the weight of each evaluation index is determined, and the corresponding grading standards should be established. After the grading standard is formulated, the actual situation of each supplier is evaluated by the experts or the supplier management personnel and the purchasing personnel, and the comprehensive evaluation result is obtained by the weighted grade method.

3.2 Grading of suppliers

According to the comprehensive evaluation score of the supplier, all suppliers would be divided into 4 grades (4A, 3A, 2A and A). There are a variety of methods to divide the data, and this paper provides 3 methods (Tab. 19):

(1) The absolute value is divided into standard, simple and intuitive, while the grading results only reflect the supplier’s own strength and performance, not affected by other suppliers

(2) 2) By division of relative to the average value of the supplier, the classification results is not only have relationship with the vendor’s own strength and performance, but also relative to other suppliers, strength, performance of the different levels assigned suppliers which have a certain relative proportion. this methods has assigned distribution characteristics;

3) The number of suppliers accounted for a certain proportion of the division, the difficulty of this method is to determine the proportion of suppliers at all levels; grading results also contained some human factors.

Taking into account the characteristics of power grid suppliers, method 1 is recommended as a supplier classification standard in Power Grid Corp

Table 19: supplier classification methods

Supplier grade	Scheme 1	Scheme 2	Scheme 3
4A	$90 \geq$	Higher than the second average value	5%
3A	80~90 (excluding 90)	Higher than the first average value Lower than the second average value	30%
2A	70~80 (excluding 80)	Lower than the first average value Higher than the third average value	50%
1A	≤ 70	Lower than the first average value	15%
			Lower than the third average value

Note: 1. The first average value is the average score of all supplier evaluation; 2. The second average value should be higher than the first average score.

3.3 Grading result argumentation

After the classification results are computed, it is necessary to demonstrate the classification results. Especially choosing method 1, if there was little or no classification of the results of the 4A suppliers or the A suppliers, the analysis of result is much more necessary.

When the experts' arguments is in accordance with the actual situation and the 4A suppliers are seldom or few, it indicates that there is still a certain gap between the category suppliers' performance and the purchaser's requirements, so suppliers need to enhance ability, to improve the quality of service, to meet the requirements of the purchaser. If the A suppliers are seldom or none, it shows that the overall situation of the supplier of the category is good, and suppliers can meet the standards and requirements of the purchasers.

If there is a big difference between the classification results and the actual results, the evaluation criteria may be too high or too low, and the managers should revise the evaluation elements or scoring standards.

The classification is a comprehensive evaluation of suppliers; it is mainly according to the supplier's own strength, and the purchase enterprise cooperation performance. The classification results show all suppliers' performance in high grade or not.

Through the classification can not only enable suppliers to understand their position in this category all suppliers, their advantages and disadvantages, so as to take corresponding improvement measures, to promote the comprehensive development, but also can make the purchasers well understand the pros and cons of a category of material supplier, general situations and individuals, so as to provide an objective basis for supplier management strategies for future suppliers provide direction.

Supplier classification management strategy is divided into these four grades:

(1) Grade 4A

The purchaser can keep close relationship with the suppliers, including technical support and joint burden of R & D expenses, and joint efforts to achieve the transfer of standardization and key technologies; the product of the supplier is preferred.

The supplier can get extra points in tender and procurement; preferential treatment in contract signing, reduction is payment, manufacturing process and quality assurance procedures inspection frequency;

Through electronic data interchange (EDI) and e-mail, suppliers can achieve communication optimization and information exchange; in the process of access to the basic materials of the bottleneck, they can get support.

(2) Grade 3A

The supplier also can get extra points in tender and procurement, the signing of the contract, payment and other links to give preferential treatment, while the discount is lower than that of 4A suppliers

The purchaser should put forward the improvement plan, the manufacturing process, inspect the suppliers' the management system and the key working procedure, and urge the supplier improve the grade.

(3) Grade 2A

According to the normal material management process; purchasers provide improvement plan, inspect the manufacturing process, management system and the key processes, strengthen quality supervision (increase the number of samples, improve the sampling rate, etc.), urge the supplier to improve the grade.

(4) Grade A

Purchasers focus on monitoring, careful selection of their products; eliminate in the procurement management.

4 Discussion

Making full use of the existing South Power Grid Corp supplier management results, this paper presents a relatively complete supplier classification system which has strong practical application basis.

And using the key indicators to track the supplier's performance, the enterprise can obtain the competitive advantage by using the same index system to evaluate all the suppliers. This evaluation method can be extended to supplier evaluation of other electric power companies,

However, classification of grid material suppliers is a complicated system process, the analysis of the classification model for the empirical in the category of other materials should be verified, the feasibility and reliability of the hierarchical model should be demonstrated in future, and the strategic application of supplier classification results should be deepen analysis.

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