AHP-based Evaluation of Management and Control Effect over Provincial Electric Power Company

Han Chen[1*], Qiyuan Cai[2], Pengjia Shi[3], Yinan Li[4], Zihan Chen[5], Jinyu Chen[6]

{307276126@qq.com[1], 492456598@qq.com[2], yoiteonkey@163.com[3], 771899992@qq.com[4], Avellen@163.com[5], 243708700@qq.com[6]}

Power Economic Research Institute of State Grid Fujian Electric Power Company, Fuzhou, China

Abstract. In order to achieve the strategic goal of building an internationally advanced energy Internet enterprise with Chinese characteristics under the new development layout of "a main body with four parts", State Grid needs to make accurate evaluation of the present management and control mode effect to seek for a method of reform. Based on the example of a provincial electric power company, this paper combines AHP and fuzzy comprehensive evaluation to evaluate the management and control mode effect from three aspects: the parent company management maturity, the subsidiary company management maturity and the parent-subsidiary consistency. Corresponding countermeasures and recommendations are proposed based on the evaluation and analysis of the management and control mode effect.

Keywords: management and control mode, AHP, a main body with four parts, analytic hierarchy process, fuzzy comprehensive evaluation

1 Introduction

Management and control mode refers to a parent-subsidiary company management system with certain characteristics, which consists of various management and control mechanisms and means [1-3]. At present, most researches on the management and control mode of electric power enterprises focus on the analysis of the composition and influencing factors of the management and control mode. For example, Xie Chuansheng et al.[4] analyzed the necessity of improving the comprehensive management and control ability of Chinese power enterprise groups based on six influential factors including enterprise development stage, business layout, development strategy, management ability, informatization degree and resource management. Rui Yi [5] proposed that the management and control system of electric power enterprises should cover the combination mode of management and control factors, core areas of electric power operation performance, benchmarking system and group annual plan formulation system. Some scholars have also studied the classification of group management and control modes, and the most common classification in academia is to divide group management and control modes into financial management and control oriented type, operational management and control oriented type and strategic management and control oriented type according to different degrees of centralization and decentralization of group headquarters [6][7]. Liu Yuehua and Wei Rong [8] took Jiangsu Electric Power Company as the research object and explored the innovative development of enterprise financial management and control-oriented mode based on bionics. Shi Junjie and Jiang Fuyou [9] chose the strategic management and

control-oriented management mode to build a strategic management system for Sichuan Electric Power Company and put forward suggestions on improving management ability.

In terms of the management and control mode of electric power company, scholars have carried out detailed studies on the composition and influencing factors of the management and control mode. In the study of provincial electric power company, scholars have done some studies on the innovation and development of specific management and control mode as well as the construction of management system. However, there are insufficient studies on the evaluation of the management and control mode effect over provincial electric power company. Zhang Chunliu and Zhang Hengquan [6] pointed out the shortcomings in selection of traditional management control mode, constructed an evaluation system, and selected appropriate group companies for application analysis. Ren Weilin [7] proposed qualitative and quantitative evaluation criteria based on the characteristics of parent-subsidiary company management and control modes in state-owned enterprises. In order to explore the present management and control mode effect over provincial electric power company, this paper constructs the evaluation system for the management and control mode of provincial electric power company on the basis of the existing literature, and takes a provincial electric power company as an example for application analysis.

2 Construction of the AHP-based evaluation system for management and control effect over provincial electric power company

2.1 Establish the hierarchical structure model of influencing factors

This paper makes a comprehensive analysis and summary of various relevant factors affecting the management and control effect of provincial electric power company, screens out the factors with a significant impact on the management and control effect to construct the management and control effect evaluation system, as shown in Figure 1.

The target layer is the evaluation of the management and control mode effect over provincial electric power company. The criterion layer is the parent company management maturity, the subsidiary company management maturity and the parent-subsidiary consistency [10][11]. Where, the parent company management maturity is used to evaluate the parent company's ability to coordinate resources between itself and its subsidiaries and among subsidiaries in provincial electric power company. Instantaneous and non-storable power products determine that the production, transportation and consumption of electric energy must be carried out synchronously, instantaneously with immediate balance. Compared with other industry groups, higher requirements are raised for the resource allocation ability of parent company [2]. The parent company operation and management level, administrator experience and professional knowledge level, risk control ability, process standardization degree and system improvement degree in the index layer under the parent company management maturity jointly affect the parent company's operation and management level [12][13]. Parent company with different diversification depth creates different effects despite the same management and control mode. Under the development layout of "a main body with four parts", the strategic diversification depth of parent company is an important factor that promotes the coordinated development of four parts [12]. The informatization level can be used to evaluate the speed of group

headquarters in downward transmission of policy information and its ability to timely discover problems in subsidiary company [14].
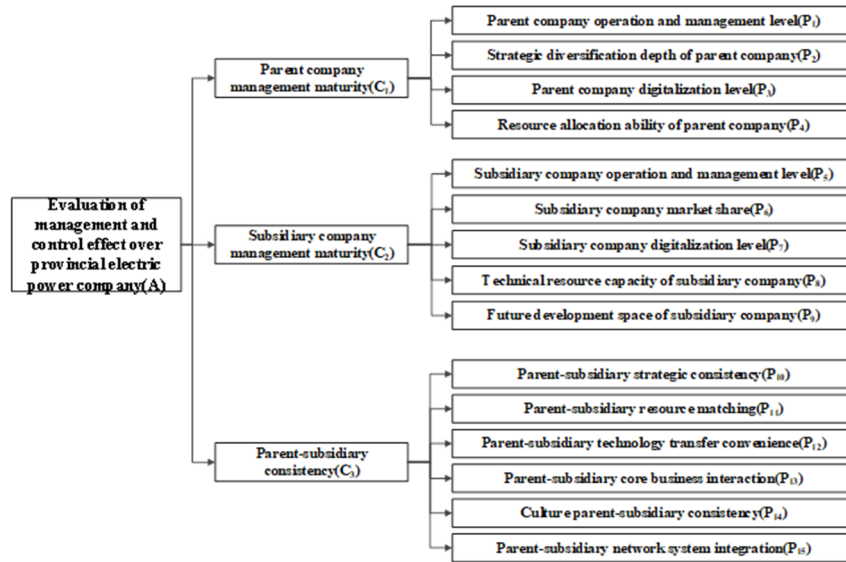
Fig. 1. Hierarchy diagram of evaluation system for management and control mode effect over provincial electric power company.

The subsidiary company management maturity reflects its own operation status, its ability to achieve expected goals and improve the group's overall benefits [15]. State Grid Corporation implements hierarchical management mode. Power grid at all levels establishes electric power companies according to administrative divisions, and different regions correspond to different subsidiary companies. The subsidiary company market share reflects the overall development status of subsidiary company and is an external reflection of the effect of the present management and control mode [12]. The operation and management level, digitization level and technical resource capacity in the index layer under the subsidiary company management maturity correspond to the operation and management level, digitization level and resource allocation ability of parent company.

The parent-subsidiary collaboration reflects the characteristics in the parent-subsidiary relationship [16]. Under higher strategic consistency and stronger parent-subsidiary resource matching, parent company can better use the internal resources of the group to provide various services for the subsidiary company, thus improving the management and control effect [17]. Instantaneous and non-storable power products, as well as parent-subsidiary core business interaction are raised to a more important position. Better results can only be achieved by focusing on top-level design to seek overall control and system optimization [2].

2.2 Construct AHP judgment matrix

The judgment matrix is used to express the relative importance of each element of the unified level in the established hierarchical structure for a certain element at the upper level [18].

When analyzing the relative importance of each element of criterion layer C for target layer A, A-C judgment matrix is constructed. The matrix is in the form $A - C = (C_{ij})_{n \times n}$, which has the following properties:

$$C_{ij} > 0, C_{ij} = 1(i = 1, 2, ..., n),$$
$$C_{ij} = 1 / C_{ji}(i, j = 1, 2, ..., n) \tag{1}$$

Where, C_{ij} represents the judgment value regarding the relative importance of the lower level element C_i for the upper level element A_k. Generally, a scale of 1-9 is used to illustrate the relative importance of each index. The value of the judgment scale is shown in Table I. For pairwise comparison between indexes, this paper collects data by expert scoring. In order to eliminate the influence of each expert's individual factors on the results, the individual weight of experts is collected into group decision weight by weighted average under the premise of consistency test [19].

Table 1. The value of the judgment scale

Scale	Definition	Description
1	Equal importance	Two elements are of equal importance in comparison
3	Slight importance	In comparison of two elements, one is more important than the other
5	Obvious importance	In comparison of two elements, one is obviously more important than the other
7	Strong importance	In comparison of two elements, one is much more important than the other
9	Extreme importance	In comparison of two elements, one is definitely More important than the other
2、4、6、8	The above two adjacent criteria	The quantitative scale under the compromise between the above two adjacent criteria
reciprocal of the above numbers	Inverse comparison	Reciprocal indicates the insignificance degree of the two compared elements

2.3 Hierarchical single ranking and consistency test

The purpose of hierarchical single ranking is to calculate the importance weight value of the related factors at this level with regard to a factor at the upper level according to the judgment matrix, which can be classified as the problem of calculating the characteristics and eigenvectors of the judgment matrix, that is, to calculate the characteristic roots and eigenvectors of the judgment matrix B when $BW = \lambda_{max} W$ is met. Where, λ is the largest feature root of B, W is the normalized feature vector corresponding to λ_{max}, the component ω_i of W is the weight in the corresponding factor ranking.

In order to test the consistency of the judgment matrix, it is necessary to calculate its consistency index CI, which is defined as

$$CI = (\lambda_{max} - n)/(n-1)$$

(2)

When $CI = 0$, the judgment matrix has complete consistency. The bigger the $\lambda_{max} - n$ is, the bigger the CI is and the lower the consistency of the judgment matrix is. In order to test whether the judgment matrix has satisfactory consistency, CI needs to be compared with the average random consistency index RI. The RI values are shown in Table II. If the random consistency ratio of the judgment matrix $CR = CI/CR < 0.10$, the judgment matrix has satisfactory consistency; otherwise, the judgment matrix needs to be adjusted.

Table 2. Average consistency index of order 1-9 matrices

Order	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

By using the above method, the judgment matrix of criterion layer versus target layer and index layer versus criterion layer are obtained and the calculation results are shown in Table III-VI.

Table 3. Judgment matrix A-C of criterion layer versus target layer and its calculation results

A Evaluation of management and control effect over provincial electric power company	C1	C2	C3	Weight(w)
Parent company management maturity(C1)	1	5	3	0.6483
Subsidiary company management maturity(C2)	1/5	1	1/2	0.1220
Parent-subsidiary collaboration(C3)	1/3	2	1	0.3288

The maximum characteristic root of the matrix $\lambda_{max} = 3.0037$; consistency index $CI = 0.0018$; average consistency index $RI = 0.58$; random consistency ratio $CR = 0.0032 < 0.10$. The judgment matrix is acceptable and the single layer weight is reasonable.

Table 4. Judgment matrix C1-P of index layer versus criterion layer and its calculation results

Parent company management maturity(C1)	P1	P2	P3	P4	Weight(w)
Parent company operation and management level (P1)	1	4	6	3	0.5649
Strategic diversification depth of parent company(P2)	1/4	1	3	2	0.2135
Parent company digitization level(P3)	1/6	1/3	1	1/2	0.0768
Resource allocation ability of parent company(P4)	1/3	1/2	2	1	0.1449

The maximum characteristic root of the matrix $\lambda_{max} = 4.0968$; consistency index $CI = 0.0323$; average consistency index $RI = 0.90$; random consistency ratio $CR = 0.0359 < 0.10$. The judgment matrix is acceptable and the single layer weight is reasonable.

Table 5. Judgment matrix C2-P of index layer versus criterion layer and its calculation results

Subsidiary company management maturity(C2)	P5	P6	P7	P8	P9	Weight(w)
Subsidiary company operation and management level(P5)	1	4	6	3	6	0.5130
Subsidiary company market share(P6)	1/4	1	1/3	1/3	1	0.0748
Subsidiary company digitization level (P7)	1/6	3	1	1/2	2	0.1328
Technical resources capacity of subsidiary company(P8)	1/3	3	2	1	3	0.2087

The maximum characteristic root of the matrix $\lambda_{max} = 5.1846$; consistency index $CI = 0.0462$; average consistency index $RI = 1.12$; random consistency ratio $CR = 0.0412 < 0.10$. The judgment matrix is acceptable and the single layer weight is reasonable.

Table 6. Judgment matrix C3-P of index layer versus criterion layer and its calculation results

Parent-subsidiary collaboration(C3)	P10	P11	P12	P13	P14	P15	Weight(w)
Parent-subsidiary strategic consistency(P10)	1	3	2	4	5	2	0.3409
Parent-subsidiary resource matching(P11)	1/3	1	2	3	4	1	0.1983
Parent-subsidiary core business interaction(P12)	1/2	1/2	1	3	5	2	0.1927
Parent-subsidiary technology transfer convenience(P13)	1/4	1/3	1/3	1	2	1/3	0.0683
Parent-subsidiary cultural consistency(P14)	1/5	1/4	1/5	1/2	1	1/3	0.0460
Parent-subsidiary network system integration(P15)	1/2	1	1/2	3	3	1	0.1538

The maximum characteristic root of the matrix $\lambda_{max} = 6.2535$; consistency index $CI = 0.0507$; average consistency index $RI = 1.24$; random consistency ratio $CR = 0.0409 < 0.10$. The judgment matrix is acceptable and the single layer weight is reasonable. After sorting out all the evaluation indexes, the comprehensive weight of the evaluation indicator system is obtained, as shown in Table VII.

Table 7. Comprehensive weight table of evaluation indexes

Criterion layer	Criterion layer weight	Index layer	Index layer weight	Indicator layer comprehensive weight
Parent company management	0.6483	P1	0.5649	0.3662
		P2	0.2135	0.1384

		P3	0.0768	0.0498
maturity(C1)		P4	0.1449	0.0939
		P5	0.5130	0.0626
		P6	0.0748	0.0091
Subsidiary company management maturity(C2)	0.1220	P7	0.1328	0.0162
		P8	0.2087	0.0255
		P9	0.0708	0.0086
		P10	0.3409	0.1121
		P11	0.1983	0.0652
Parent-subsidiary collaboration(C3)	0.3288	P12	0.1927	0.0634
		P13	0.0683	0.0225
		P14	0.0460	0.0151
		P15	0.1538	0.0506

3 Evaluation of management and control mode of a provincial electric power company based on fuzzy comprehensive evaluation method

3.1 Establish fuzzy comprehensive evaluation factor set and comment set

Take the power generation data of Sichuan Province in 2011 as an example, as shown in Fig. 1, in which the total power generation is 18

U is the set composed of all evaluation indexes in comprehensive evaluation, $U = \{u_1, u_2, ..., u_n\}$. Where, $u_i (i = 1, 2, 3, ..., n)$ is the evaluation index factor; Target layer: U= {evaluation of management and control effect over provincial electric power company}; Criterion level: U={ u_1, u_2, u_3, u_4 }={parent company management maturity, subsidiary company management maturity, parent-subsidiary collaboration}

Index layer: $u_1 = \{u_{1i}\}$ = {Parent company operation and management level, strategic diversification depth of parent company, parent company digitalization level, resource allocation ability of parent company}. $u_2 = \{u_{2i}\}$ = {subsidiary company operation and management level, subsidiary company market share, subsidiary company digitization level, technical resource capacity of subsidiary company, future development space of subsidiary company}. $u_3 = \{u_{3i}\}$ ={parent-subsidiary strategic consistency, parent-subsidiary resource matching, parent-subsidiary technology transfer convenience, parent-subsidiary core business interaction, parent-subsidiary cultural consistency, parent-subsidiary network system integration}

The comment set V of evaluation factors was established. Comment set is a set of evaluation results made by evaluators on the evaluation object. $V = \{v_1, v_2, ..., v_n\}$ .Where, $v_j (j = 1, 2, 3, ..., n)$ is the jth evaluation result, and each level equals to a fuzzy subset. The comments herein are collected by expert scoring method. In this paper, the evaluation set is divided into five levels to construct V= {strong, relatively strong, general, relatively weak, weak} and evaluate the management and control mode effect over a provincial electric power company. Values {100,80,60,40,20} are assigned in turn. The expert scoring rules are shown in Table VIII.

3.2 Establish fuzzy relation matrix

A survey was conducted on the administrators of a provincial electric power company and professors of power-related major, and 39 pieces of valid survey data were collected. The single factor evaluation matrix of the parent company management maturity index can be obtained according to the data, as shown in Table IX. Similarly, other single-factor fuzzy relation matrices can be obtained, as shown in Table X and Table XI.

Table 8. Expert scoring rules

Evaluation level	Strong	Relatively strong	General	Relatively weak	Weak
Score range	90~100	80~90	60~80	40~60	<40

Table 9. R_1 single factor evaluation matrix

Index	V_1	V_2	V_3	V_4	V_5
u_{11}	4/13	7/13	2/13	0	0
u_{12}	3/13	8/13	1/13	1/13	0
u_{13}	3/13	1/13	6/13	3/13	0
u_{14}	3/13	7/13	3/13	0	0

Table 10. R_2 single factor evaluation matrix

Index	V_1	V_2	V_3	V_4	V_5
u_{21}	1/13	5/13	7/13	0	0
u_{22}	2/13	5/13	6/13	0	0
u_{23}	1/13	2/13	4/13	5/13	1/13
u_{24}	2/13	3/13	6/13	2/13	0
u_{25}	2/13	6/13	5/13	0	0

Table 11. R_3 single factor evaluation matrix

Index	V_1	V_2	V_3	V_4	V_5
u_{31}	6/13	7/13	0	0	0
u_{32}	3/13	7/13	3/13	0	0
u_{33}	3/13	8/13	2/13	0	0
u_4	3/13	3/13	7/13	0	0
u_{35}	5/13	7/13	1/13	0	0
u_{35}	3/13	5/13	2/13	3/13	0

3.3 Conduct fuzzy comprehensive evaluation

Evaluation set V=[100 80 60 40 20]. After determining the membership degree of the evaluation set, the single factor fuzzy matrix and the total evaluation matrix are obtained for the evaluation of the management and control mode effect over a provincial electric power company and the scores are calculated. The weight vector of each index is:

$$W1=[0.5649\ 0.2135\ 0.0768\ 0.1449] \tag{3}$$
$$W2=[0.5130\ 0.0748\ 0.1328\ 0.2087\ 0.0708] \tag{4}$$
$$W3=[0.3409\ 0.1983\ 0.1927\ 0.0683\ 0.0460\ 0.1538] \tag{5}$$
$$C1=W1\cdot R1=[0.2742\ 0.5195\ 0.1722\ 0.0341\ 0] \tag{6}$$
$$A1=C1\cdot VT=80.6828 \tag{7}$$

This shows that the parent company management maturity is at a high level.

$$C2=W2\cdot R2=[0.1042\ 0.3273\ 0.4752\ 0.0832\ 0.0102] \tag{8}$$
$$A2=C2\cdot VT=68.6480 \tag{9}$$

This shows that the subsidiary company management maturity is at an average level.

$$C3=W3\cdot R3=[0.3165\ 0.5086\ 0.1394\ 0.0355\ 0] \tag{10}$$
$$A3=C3\cdot VT=82.1229 \tag{11}$$

This indicates that the parent-subsidiary collaboration is at a high level. The index layer membership is combined to obtain the criterion layer membership:

$$R=\begin{bmatrix} C_1 \\ C_2 \\ C_3 \end{bmatrix}=\begin{bmatrix} 0.2742 & 0.5195 & 0.1722 & 0.0341 & 0.0000 \\ 0.1042 & 0.3273 & 0.4752 & 0.0832 & 0.0102 \\ 0.3165 & 0.5086 & 0.1394 & 0.0355 & 0.0000 \end{bmatrix} \tag{12}$$

The evaluation results of the management and control mode effect over a provincial electric power company are as follows, and the final score is shown in Table XII.

$$W=[0.6483\ 0.1220\ 0.3288] \tag{13}$$
$$C=W\cdot R=[\ 0.2946\ 0.5440\ 0.2154\ 0.0440\ 0.0012] \tag{14}$$
$$A=C\cdot VT=87.6837 \tag{15}$$

Table 12. Final score in evaluation of management and

Index	Parent company management maturity	Subsidiary company management maturity	Parent-subsidiary collaboration	Evaluation of management and control mode effect over a provincial electric power company
Score	80.6828	68.6480	82.1229	87.6837

4 Analysis on comprehensive evaluation results of management and control mode effect over a provincial electric power company

According to the comment set, the corresponding score and grade setting, and the final calculation results (see Table XII), it can be seen that the management and control mode effect over a provincial electric power company is at a relatively strong level in terms of parent company management maturity and parent-subsidiary collaboration, but at a general level in terms of subsidiary company management maturity.

The parent company management maturity reflects the parent company's supervision ability, strategic planning and execution ability, and the perfection of the system, etc. The strategy, audit system and business norms formulated by the parent company form the basic basis for the enterprise group to implement subsidiary supervision [13]. The single factor evaluation matrix reflects that among the four indexes of parent company management maturity, operation and management level performs well, and all the experts participating in the survey gave average scores or above. At the same time, because of the great weight of this index, the company's performance in this index has laid a good foundation for the overall performance of this criterion layer. The parent company digitalization level has the biggest room for improvement. Among the 39 experts involved in the survey, 27 gave average or weak scores. Although this index weight is not high at present, it can be seen from the above analysis that digitalization has become a strategic choice for grasping the new opportunities in the new round of scientific and technological revolution and industrial transformation. Enhancing company digitalization level can provide greater development space for the future of the group.

The subsidiary company management maturity is the ability of subsidiary company to use its material and knowledge resources, effectively achieve predetermined goals and meet the group's strategic needs [15]. The single factor evaluation matrix reflects that subsidiary company digitalization level is the weakest among the five indexes of subsidiary company management maturity. 18 experts gave a relatively weak or weak score, and 12 experts gave a general score. At the same time, it can be seen that subsidiary company has significantly lower digitalization level than parent company. In terms of digitalization level, the group needs to boost collaborative enhancement of the subsidiary company by improving parent company digitalization level. In order to adapt to the changing trend of the environment, State Grid proposed a mixed management and control mode of "strategy + finance" and "strategy + operation" in view of its own development needs [20]. This mode can delegate power and stimulate grassroots functions, which is expected to continuously improve the subsidiary company management maturity in practice. At the same time, the building of parent company

core competitiveness at the operation level can help subsidiary company improve its strategic execution ability and operational performance, thus facilitating the formation of synergies among business segments and subsidiary companies.

The parent-subsidiary collaboration reflects the characteristics of the parent-subsidiary relationship from the side. However, parent-subsidiary technology transfer convenience and the current management and control mode are not well matched, which needs to be further strengthened. A total of 21 experts gave average scores. Under lower parent-subsidiary technology transfer difficulty, the group agglomeration is higher, which better suits the current management and control mode of a provincial electric power company [12]. The technology transfer convenience can also be adjusted by digital transformation. Digital technological change can increase the effectiveness and accuracy of management and control work in an all-round way [21]. Therefore, the group can synchronously improve the level of related indexes by using the links between indexes. At present, the company is at a strong level in terms of strategic consistency and overall collaboration. Steady improvement is needed while maintaining the existing level.

5 Conclusions

The management and control mode is the key task in the reform of state-owned enterprises, the objective drive for the power grid company to adapt to the new layout of "a main body with four parts", and the important guarantee for the smooth implementation of the energy Internet strategy of the State Grid Company. The paper puts forward the following countermeasures and recommendations.

5.1 Formulate unified planning of strategic objectives and implementation plans to improve parent-subsidiary synergistic effect

For provincial electric power companies, strategic planning is the decisive guiding ideology for their development and the necessary prerequisite to guarantee their healthy and sustainable development. On the premise of formulating scientific and reasonable strategic planning, the parent company also needs to clarify the parent-subsidiary decentralization and respective responsibilities and rights. In the process of power distribution, it is not only necessary to ensure the reasonable allocation of responsibilities, powers and interests, but also to effectively guarantee the subject initiative of all departments and subsidiaries within the group.

5.2 Focus on the improvement of digitalization level

For the decision-making related to the management and control mode of a provincial electric power company, it is necessary to determine a scientific and reasonable management and control mode after detailed analysis and research on the dynamic changes inside and outside the enterprise based on the Internet big data technology.

5.3 Formulate unified planning of strategic objectives and implementation plans to improve parent-subsidiary synergistic effect

By comprehensive consideration of the actual development status, industry characteristics and regional culture of the enterprise group, it is necessary to establish a good cultural system that

can promote employees' cohesion and sense of professional responsibility. In the process of implementation, it is necessary to fully mobilize the subjective initiative of each subsidiary company, encourage all members to participate in the process, and encourage them to offer suggestions for the improvement of the corporate culture system.

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