Research Article
Study on Social Benefits Evaluation System of Electrical Power Inspection Based on FAHP

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Abstract: In order to evaluate social benefits in electrical power inspection scientifically and assess social responsibility performance of power supply enterprises roundly and rationally, social benefits evaluation system of electrical power inspection based on FAHP was constructed in this study. Firstly, social benefits evaluation index system of electrical power inspection was established based on its basic work programs and impacts on various aspects of social life; secondly, a Fuzzy-AHP model was constructed based on combination of AHP and fuzzy comprehensive evaluation and finally, an empirical test was done. It turns out that the model is both scientific and operable.

Keywords: AHP, electrical power inspection, fuzzy comprehensive evaluation, social benefits

INTRODUCTION

With the acceleration of the process of urban modernization and increase of types and quantity of electrical equipment, electricity consumption presents the trend of rapid growth. As a result, Some power supply enterprises focus on electricity market development and modernization, without paying enough attention to infrastructure management, exposing a lot of vulnerability in line loss management, average electricity prices, wholesale electricity, electricity security, electricity trading, electricity recycling, metering management, meter reading management, business expanding project management, economic dispatch, moral construction and quality services, accidents have occurred from time to time, not only caused serious economic losses, but also affected the social image of the power supply enterprises. In response to these circumstances, some power supply enterprises have carried out electrical power inspection and gradually established a power inspection system, which has made great achievements in terms of increasing income and standardized management, while producing tremendous social benefits. Research on electrical power inspection is mainly focused on two aspects: basic theories of electrical power inspection and management of electrical power market inspection.

It is suggested that electrical power inspection could be improved by strengthening supervision of marketing quality, improving internal mechanisms management and construction of electrical power inspection, strengthening the fight against illegal use of electricity and stealing behaviors, improving quality service and style construction supervision and so on Yue (2011). Li (2010) proposed measures to strengthen electrical power inspection mechanisms, analyzed key points of electrical power inspection in-depth and pointed out how to handle a variety of marketing inspection relations. Zhao (2008) analyzed the concept of administrative law enforcement and inspection of electrical power in detail, including connotations, extensions and relationships between them, as well as functions and features of electrical power inspection, which is very helpful to carry out administrative law enforcement and electrical power inspection correctly. Gao (2006) introduced business of U.S. electrical power market inspection. Frank (2004) discusses process of electrical power inspection and its independence based on experience of electrical power inspection in the United Kingdom, the United States, California, New Zealand, Spain and other countries. Rahimi and Sheffri (2003) introduced the functions of electrical power market inspection and the various functional indicators, tools, data requirements, market monitoring system, key components of to accomplish the functions.

AHP and fuzzy comprehensive evaluation are very popular in conducting evaluation. Niu and Cong (2010) used the Analytic Hierarchy Process (AHP) and multi-level fuzzy comprehensive evaluation method to evaluate the thermal power plant project impacts, proposed the problems in the current project impact post-evaluation and conducted qualitative and quantitative evaluation of the thermal power plant

project. Li and Jianfei (2012) divided innovation urban environment into four parts, constructed evaluation index system of urban innovation environment and constructed a comprehensive evaluation model based on the Analytic Hierarchy Process. Yang and Xing (1993) gave a synthetic evaluation to enterprise economic benefit and supply information for decision making and its scientific management by using the Analytical Hierarchy Process (AHP) method. Wan and Zhu (2008) applied Analytic Hierarchy Process (AHP) to assign the weights of indicators and used fuzzy comprehensive evaluation method to compute the present currency value of patent in order to evaluate patent value.

In conclude, comprehensive evaluation modes and methods are already quite mature, while no scientific evaluation of social benefits of electrical power inspection has been conducted by now. Objective of the study is assess social responsibility performance of power supply enterprises roundly and rationally by construction of social benefits evaluation system of electrical power inspection, helping them identify problems, achieve experience and carry out electrical power inspection more effectively.

CONSTRUCTION OF SOCIAL BENEFITS EVALUATION SYSTEM OF ELECTRICAL POWER INSPECTION

Design principles of the evaluation index system:

- **Systematic principle**: In order to get a comprehensive, integrated and standardized reflection of the relationship between indicators of the social benefits evaluation system of electrical power inspection and their connection with external environment, Social benefits evaluation system of electrical power inspection should be designed in accordance with systematic principle and build a reasonable and clear hierarchy
- **Factual principle:** Evaluation system of electrical power inspection should be able to truly reflect the essential characteristics and law of development of electrical power inspection; and the evaluation index system should also be able to fully and truly reflect the characteristics, state, dynamics and trends of each evaluation factor
- **Principle of comparability:** The entire evaluation index system should be applied in the evaluation of the effectiveness of all kinds of electric power supply enterprises, which means it should not only used for longitudinal comparisons that make social benefits of electrical power inspection of the same area at different times comparable, but also can be used for horizontal comparisons that make social benefits of electrical power inspection between different areas comparable

- **Principle of testability:** This principle includes two aspects: First, the quantitative indicators can be measured or calculated using existing tools, qualitative indicators can be transformed into other indirect indicators that can be measured quantified; second, sufficient data and information should be ensured in the evaluation process

Construction of the evaluation index system: Social benefits of electrical power inspection represent the contribution of electrical power inspection to society. Based on the basic work program and its impact on all levels of society, this study established a social benefits evaluation system of electrical power inspection including the following five aspects: promotion of regional economic development, benefits of people's lives, benefits of social stability, benefits of safeguard electricity order and environmental benefits.

First, based on frequency analysis, theoretical analysis and social benefits of electrical power inspection, statistical analysis of various indicators from many domestic and foreign research literatures were done; second, those indicators with high frequency and strong points were selected; third, 10 experts of related field were chosen to select the above indicators by using Delphi method. And the final results are shown in Table 1.

Meanings of the indicators:

- **Regional economic income increase (C_{11}):** Total revenue of the regional economy by improving power supply reliability, reducing outage time with the help of electrical power inspection. The indicator is calculated as follows:

$$C_{11} = \Delta t \times I$$

where,
Δt = Total blackout time reduction with the help of electrical power inspection during the calculation period (hour)
I = The average GDP output per hour within the regional, (million/hour), which can be calculated by selecting the average GDP output of representatives of three major industrial users.

- **Reduction rate of residential electricity blackouts (C_{21}):** Proportion of average residential electricity blackouts reduction with the help of electrical power inspection accounts average residential electricity blackouts without the help of electrical power inspection. The indicator is calculated as follows:

Table 1: Social benefits evaluation system of electrical power inspection

	Promotion of regional economic development (B₁)	Regional economic income increase(C₁₁)
Social benefits of electrical power inspection(A)	Benefits of people's lives (B₂)	Reduction rate of residential electricity blackouts (C₂₁)
		Satisfaction of residential electricity consumption (C₂₂)
	Benefits of social stability (B₃)	Reduction frequency of security incidents crime(C₃₁)
		Reduction of social contradictions (C₃₂)
	Benefits of safeguard electricity order (B₄)	Reduction rate of illegal use of electricity, stealing behavior (C₄₁)
		Regulation of electricity market(C₄₂)
	Environmental benefits (B₅)	Reductions of carbon emission (C₅₁)

$$C_{21} = \frac{t_0 - t_1}{t_0}$$

where,

t_0 = Average residential electricity blackouts without the help of electrical power inspection (hours)

t_1 = Average residential electricity blackouts with the help of electrical power inspection (hours)

t_0, t_1 = Calculated by using data from electrical power inspection records.

- **Satisfaction of residential electricity consumption (C₂₂):** Increase of satisfaction of residential electricity consumption with the help of electrical power inspection. It includes improving service quality and efficiency by establishing and perfecting quality service and style construction inspection and supervision mechanism, strengthening service quality and efficiency, reducing life electricity power outage repair time and waiting time to pay the electricity bills, which can improve satisfaction of residential electricity consumption; electrical power inspection can inspect around "organ style, power supply, installation and construction, electricity bills charges", which can solve the problem of" arbitrary charges, levies and indiscriminate increase " and improve satisfaction of residential electricity consumption; electrical power inspection can inspect orderly power management to ensure production needs, reduce the loss of key enterprises blackout and at the same time to ensure that the public electricity is not affected, which can also raise electricity customers' satisfaction. This indicator can be measured by survey methods

- **Reduction frequency of security incidents crime (C₃₁):** Since frequency of security incidents crime during a power outage is significantly higher than that of normal power supply and outage time can be greatly reduced by electrical power inspection, which means electrical power inspection can also reduce frequency of security incidents crime. The indicator expresses the number of security incidents crime reduced by examining the whole

process of power supply. The indicator is calculated as follows:

$$C_{31} = \Delta t \times C$$

In which, Δt-total outage reduction by electrical power inspection during the calculation period (hours), which can be found from electrical power inspection annual report; C- the average frequency of security incidents crime during a power outage (times/hour), which can be obtained by querying the criminal records of security incidents in the area.

- **Reduction of social contradictions (C₃₂):** The blackout will cost loss and inconvenience to residential production and life, causing social contradictions. The indicator expresses reduction number of social conflicts and disputes by reducing outage time with the help of electrical power inspection. This indicator can be obtained by comparing the number of social conflicts and disputes with and without electrical power inspection

- **Reduction rate of illegal use of electricity, stealing behavior (C₄₁):** Reduction rate of illegal use of electricity, stealing behavior before and after implementation of electrical power inspection. It reflects the social benefits of electrical power inspection in protecting electricity order. The indicator is calculated as follows:

$$C_{41} = \frac{n\text{-}m}{n} \times 100\%$$

In which, n-number of illegal use of electricity, stealing behavior before implementation of electrical power inspection, m-number of illegal use of electricity, stealing behavior after implementation of electrical power inspection.

- **Regulation of electricity market (C₄₂):** Safeguard electricity order benefits caused by inspecting electricity dealings, tariff recovery, measurement management, meter reading management, industry expansion project management of electricity supply units. It focuses on power management order inspection and can be measured by using Delphi method

- **Reductions of carbon emission (C_{51}):** Reductions of carbon emission by inspection of business survey and the high loss line station area to promote the whole line loss rate reduction of the region, improve energy efficiency and reduce carbon emissions. The indicator is calculated as follows:

$$C_{51} = (X_0 - X_1) \times T_{sl} \times Q_c$$

where,

X_0 = The average line loss rate before implementation of electrical power inspection

X_1 = The average line loss rate after implementation of electrical power inspection

T_{sl} = The power supply after implementation of electrical power inspection during the calculate period(kWh)

Q_C = the carbon emissions generated by producing 1kWh electrical energy (kg/kW•h), which can be calculated by the carbon calculator

X_0, X_1 = The electrical power inspection management information system

SOCIAL BENEFITS EVALUATION MODEL OF ELECTRICAL POWER INSPECTION BASED ON FAHP

Social benefits evaluation system of electrical power inspection is a complex system of indicators and indicators with different weights of each level are closely linked to each other, so AHP method was used to determine the index weights.

To determine the index weights by using AHP:

- **Construction of judgment matrix:** First, hierarchical decomposition of social benefits of electrical power inspection was made, achieving the formation of multi-level structure composed by a number of influencing factors, including target layer, criteria layer and index layer. Second, judgment matrix of each level was constructed based on the 1-9 judgment matrix proposed by professor Satty.
- **Determine the index weight value:** The weight calculation method used in this study is as follows: standardize the n-th power root of each row of the elements of the judgment matrix constructed above and the corresponding weight vector is:

$$W = \begin{bmatrix} \omega_1 & \omega_1 & \cdots & \omega_n \end{bmatrix}^T \ (\ \omega_i = \overline{\omega_i} / \sum_{j=1}^n \overline{\omega_j} \ , \ \overline{\omega_i} = \sqrt[n]{\prod_{j=1}^n a_{ij}} \ )$$

(Niu and Xu, 2010)

- **Consistency test:** Consistency test of the judgment matrix should be made because of the effect of the complex evaluation system and incomplete expert system. Relative consistency index:

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

among which,

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

n represents order of the judgment matrix, λmax means the largest eigenvalue of the judgment matrix and

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^n (AW) / \omega_i$$

RI means average random consistency index values, as is shown in Table 2. If $n = 1/2$, the judgment matrix is with complete consistency, $CR = 0$; if $n>2$, $CR<0.1$, the judgment matrix has satisfactory consistency, otherwise the judgment matrix needs correction (Li and Jianfei, 2012).

Fuzzy comprehensive evaluation: Fuzzy comprehensive evaluation method is a kind of comprehensive evaluation method that transforms qualitative evaluation into quantitative evaluation based on degree of membership in fuzzy math theory, it is clear and systemic. This method can solve fuzzy and qualitative problems effectively and the basic steps are as follows:

- Determine the evaluation factor sets $U = \{u_1, u_2, \cdots u_n\}$
- Determine the review sets, which represent factors centralized collection of reviews of each factor

$$V = \{v_1, v_2, \cdots, v_m\}$$

- Single factor fuzzy evaluation, that is, to determine the evaluation object membership of the various elements of the review set by starting from an index I, $R_i = [r_{i1}, r_{i2}, \cdots; r_{im}]$
- Multi-level fuzzy comprehensive evaluation, fuzzy comprehensive evaluation matrix of the criteria layer is $B_i = W_i \circ R_i$, among which, W_i represents the weight vector and ' $\circ$ ' represents generalized fuzzy operator; in a similar way, fuzzy comprehensive evaluation matrix of the target layer is $B = W \circ R$.

Table 2: Average random consistency index values (RI)

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Table 3: Index weight values of electrical power inspection social benefits of a certain province

Criteria layer	Weight	Index layer	Weight
Promotion of regional economic development (B_1)	0.123	Regional economic income increase(C_{11})	1.00
Benefits of people's lives (B_2)	0.162	Reduction rate of residential electricity blackouts (C_{21})	0.60
		Satisfaction of residential electricity consumption (C_{22})	0.40
Benefits of social stability (B_3)	0.473	Reduction frequency of security incidents crime(C_{31})	0.40
		Reduction of social contradictions (C_{32})	0.60
Benefits of safeguard electricity order (B_4)	0.095	Reduction rate of illegal use of electricity, stealing behavior (C_{41})	0.44
		Regulation of electricity market (C_{42})	0.56
Environmental benefits (B_5)	0.147	Reductions of carbon emission (C_{51})	1.00

Finally, the rated score is derived by percentage system and standard grade of social benefits evaluation system of electrical power inspection is determined by comparing with given levels.

INSTANCE ANALYSIS

Examine the comprehensive evaluation index system and FAHP model established above by taking an electrical power inspection bureau as an example and concrete steps are as follows:

- **Determine the index weight value based on AHP method:** According to the calculation of the analytic hierarchy process and the judgment matrix consistency test, weight of index at all levels of Social benefits evaluation system of electrical power inspection is shown in Table 3.

Therefore, index weight vectors of all levels are as follows:

$$W = \begin{bmatrix} 0.123 & 0.162 & 0.473 & 0.095 & 0.147 \end{bmatrix}^T$$

$$W_1 = \begin{bmatrix} 1.00 \end{bmatrix}, W_2 = \begin{bmatrix} 0.60 & 0.40 \end{bmatrix}^T$$

$$W_3 = \begin{bmatrix} 0.40 & 0.60 \end{bmatrix}^T W_4 = \begin{bmatrix} 0.44 & 0.56 \end{bmatrix}^T W_5 = \begin{bmatrix} 1.00 \end{bmatrix}$$

- **Determine the review set:** According to the characteristics of social benefits evaluation system of electrical power inspection, the review set of social benefits of electrical power inspection was divided into "excellent, good, poor" three levels and thus constitute a remark set:

$$V = \{v_1, v_2, v_3\} = \{excellent, \quad good, \quad poor\}$$

- **Single factor fuzzy evaluation:** Judgment matrixes of subjective indicators such as satisfaction of residential electricity consumption (C_{22}), regulation of electricity market (C_{42}) were determined by using the fuzzy statistical method; Judgment matrixes of objective indicators such as regional economic income increase (C_{11}), reduction rate of residential electricity blackouts (C_{21}),

reduction frequency of security incidents crime (C_{31}) were calculated by using the membership function

SINGLE FACTOR FUZZY EVALUATION BASED ON FUZZY STATISTICAL METHOD

Judgment matrixe of "satisfaction of residential electricity consumption C_{22}" should be determined by using the fuzzy statistical method, because it is a subjective indicator. 10 experts in the field were invited to evaluate the effect on satisfaction of residential electricity consumption of the company's electrical power inspection and the evaluation results are shown in Table 4. Therefore, the fuzzy evaluation matrix of indicator :

$$C_{22} \text{ is } R_{22} = \begin{bmatrix} 0.2 & 0.6 & 0.2 \end{bmatrix}$$

Similarly, the fuzzy evaluation matrix of indicator C_{42} is $R_{42} = \begin{bmatrix} 0.4 & 0.6 & 0 \end{bmatrix}$.

Single factor fuzzy evaluation based on membership function: Judgment matrixe of "satisfaction of residential electricity consumption C_{11}" should be determined by using membership function, because it is an objective indicator. First, representative value corresponding to three level fuzzy subset of excellent, good and poor of indicator C_{11} was determined. Since there is still no reference standard of this indicator, values of C_{11} during August 2010 and June 2011 in the nine branches of this electrical power inspection bureau were listed in descending order and the biggest value 22.19% of the Branch B was selected to represent the standard "excellent" and the smallest value 6.03% of the Branch E was selected to represent the standard "poor" and the intermediate value 14.11% was selected to represent the standard "good". Membership functions $\mu_1(x)$, $\mu_2(x)$ and $\mu_3(x)$ were shown as follows:

$$\mu_1(x) = \begin{cases} 0 & 14.11 \le x \\ \dfrac{14.11 - x}{14.11 - 6.03} & 6.03 < x < 14.11 \\ 1 & 0 \le x \le 6.03 \end{cases}$$

Table 4: Expert evaluation grade frequency tables

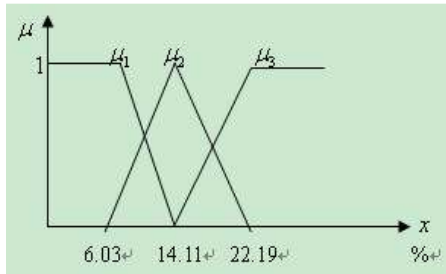| Indicator	Excellent	Good	Poor
C_{22}	2	6	2

Fig. 1: Membership function images of satisfaction of residential electricity consumption

$$\mu_3(x)=\begin{cases} 0 & others \\ \dfrac{x\text{-}14.11}{22.19-14.11} & 14.11 < x < 22.19 \\ 1 & 22.19 \le x \end{cases}$$

$$\mu_3(x)=\begin{cases} 0 & others \\ \dfrac{x\text{-}14.11}{22.19-14.11} & 14.11 < x < 22.19 \\ 1 & 22.19 \le x \end{cases}$$

Membership function images of satisfaction of residential electricity consumption were shown in Fig. 1.

Value of C_{11} during August 2010 and June 2011 of this electrical power inspection bureau is:

$$C_{11}=\frac{\Delta t_2 \times \overline{I}}{I}\times100\%=\frac{408\times4.88}{14246.11}\times100\%=13.97\%, \quad thus,$$

$R_{11}=\begin{bmatrix} 0 & 0.983 & 0.017 \end{bmatrix}$.

Similarly, single factor fuzzy evaluation matrixes of reduction rate of residential electricity blackouts (C_{21}), reduction frequency of security incidents crime (C_{31}), reduction of social contradictions (C_{32}), reduction rate of illegal use of electricity, stealing behavior (C_{41}) and reductions of carbon emission (C_{51}) are as follows:

$R_{21}=\begin{bmatrix} 0.391 & 0.609 & 0 \end{bmatrix} R_{31}=\begin{bmatrix} 0.284 & 0.716 & 0 \end{bmatrix}$
$R_{32}=\begin{bmatrix} 0.067 & 0.933 & 0 \end{bmatrix}$

$R_{41}=\begin{bmatrix} 0.481 & 0.519 & 0 \end{bmatrix} R_{51}=\begin{bmatrix} 0 & 0.677 & 0.323 \end{bmatrix}$

- **Multi-level fuzzy comprehensive evaluation:** Fuzzy relationship synthesis was made based on single factor fuzzy evaluation and we can get
$B_1=W_1\circ R_1=\begin{bmatrix} 0 & 0.983 & 0.017 \end{bmatrix}$

Similarly,

$B_2=W_2\circ R_2=\begin{bmatrix} 0.315 & 0.605 & 0.08 \end{bmatrix} B_3=W_3\circ R_3=\begin{bmatrix} 0.154 & 0.846 & 0 \end{bmatrix}$

$B_4=W_4\circ R_4=\begin{bmatrix} 0.436 & 0.564 & 0 \end{bmatrix}$

$B_5=W_5\circ R_5=\begin{bmatrix} 0 & 0.667 & 0.323 \end{bmatrix}$

$B=W\circ R=\begin{bmatrix} 0.165 & 0.772 & 0.063 \end{bmatrix}$

Comprehensive evaluation results: Percentage system was chosen based on comprehensive evaluation vector, assume that 100 points represents "excellent", 70 points represents "good" and 30 points represents "poor" , thus comprehensive score K is:

$$K=0.165\times100+0.772\times70+0.063\times30=72.43$$

Divide social benefits of electrical power inspection into three levels between 0-100 points:

0-60 points, "social benefits of non-compliance" status
60-80 points, "social benefits of compliance" status
80-100 points, "social benefits of excellent" status

According to this standard, the conclusion is that the status of social benefits of this electrical power inspection is in "social benefits of compliance" and it will have to work a little harder to achieve the "social benefits of excellent" status.

CONCLUSION

Based on principles of systematicness, factuality, comparability and testability, social benefits evaluation system of electrical power inspection was established including the following five aspects: promotion of regional economic development, benefits of people's lives, benefits of social stability, benefits of safeguard electricity order and environmental benefits. And then, a comprehensive evaluation model was constructed by using fuzzy analytic hierarchy process. Finally, an instance was analyzed to prove feasibility of the model. Combination of AHP and fuzzy comprehensive evaluation, not only eliminates a purely subjective evaluation of the indicators in empowerment process and the use of the membership function also makes qualitative factors quantified, enhancing practicality and operability of the model, which is has important value and practical significance.

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