Research on the Life Cycle Decision Model for the Impact of Power Industry Expansion

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Abstract: In the daily operation and management of electric power companies, the expansion of the power industry is a very critical link, which is easily affected by a variety of factors. In order to further accurately measure the contribution of industry expansion to electricity, determine the life cycle stage of the impact of power industry expansion, and a life cycle decision model for the impact of power industry expansion is studied. Logistic is used to build an evolutionary curve model for the impact of power industry expansion. Based on TICHY's life cycle model of industrial clusters, the evolutionary life cycle stages for the impact of power industry expansion are analyzed. Fuzzy sets are used to describe the characteristics of each stage of the life cycle for the impact of power industry expansion. By determining the fuzzy set and fuzzy relation matrix, the life cycle judgment model is determined based on the fuzzy closeness. The experimental results show that the judgment results of the design model are basically consistent with the direct observation results, and the judgment accuracy is always higher than 90%, the judgment time is less than 25ms, which can effectively determine the life cycle stage of the impact of power industry expansion, and accurately measure the contribution of industry expansion to electricity.

Keywords: Power industry expansion; Logistic; Life cycle; Fuzzy set; Judgment model

1 INTRODUCTION

As an important energy, the whole service process of power is concerned by people in all fields. Therefore, power supply companies must strengthen close contact with customers to ensure the normal operation and maintenance of the power system [1-2]. The so-called "power industry expansion and installation" refers to the power supply license and equipment installation for users, the maintenance of power supply equipment, and the power supply for users [3-4]. In the whole process of power industry expansion and installation, power supply companies must meet the needs of power customers, and the acceptance, dispatch and installation and work efficiency of power supply companies will directly affect the work quality of power supply companies, which is also an important part of power supply enterprises. In order to further accurately measure the contribution of industrial expansion to electricity, the concept of the impact of industrial expansion on the life cycle is proposed during the statistical prediction of long-term high-voltage users' industrial expansion contribution to electricity, and the impact of industrial expansion on the life cycle of each

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industry's expansion business is defined to achieve a scientific measurement of the power contributed by industrial expansion.

At present, scholars in related fields have studied the life cycle decision model. Reference [8] (Wei, 2021) proposed the supply chain replenishment decision of multi cycle short life cycle news suppliers' products. In this study, a new multi period model is developed to determine multiple replenishment decisions for products in short sales seasons. This study not only shows the profit function of retailers, but also provides the profit function for manufacturers and the entire channel in the supply chain problem. The proposed multi period ordering model provides a clear insight into how retailers' ordering decisions are affected in a specific period by considering unsold inventory or unsatisfied demand in the previous period. Numerical analysis and simulation results show that the model is feasible. Reference [1] (Arshad, 2021) proposed road infrastructure project evaluation: a decision-making method based on life-cycle sustainability. This study proposes a project evaluation tool based on life cycle sustainability, including evaluation framework, integration model and decision-making framework. In the first phase, a framework for assessing the life cycle sustainability of road infrastructure was established using a hybrid approach. In the second stage, interviews are conducted to obtain paired comparisons between impact categories and subjective reasoning about their priorities. The integrated model of sustainability assessment is established by using the analytic hierarchy process. Assess the minimum threshold limits for impact categories and incorporate them into the proposed decision-making framework. In addition, a thematic and cross-sectional analysis of the interview results was carried out to rationalize the proposed decision-making framework. The research results include a detailed customized project evaluation framework, an integration model and a decision-making framework for evaluating different project alternatives. This study helps policy makers and decision-makers to choose project alternatives by maximizing the sustainability of road infrastructure projects. In addition, it also realizes the in-depth understanding of environmental and social externalities and their quantitative interpretation in the service life of roads [5-6].

Based on the above analysis, a life cycle decision model for the impact of power industry expansion is studied. By building an evolutionary curve model for the impact of power industry expansion, the stages of the evolutionary life cycle are analyzed and the characteristics of each stage of the life cycle are described. By determining the fuzzy set, fuzzy relation matrix and life cycle decision model, the life cycle decision oriented to the impact of power industry expansion is realized. This model can effectively determine the life cycle stage of the impact of power industry expansion, and accurately measure the contribution of industry expansion to electricity.

2 EVOLUTIONARY CURVE MODEL FOR THE IMPACT OF POWER INDUSTRY EXPANSION

2.1 Construction of evolutionary curve model for the impact of power industry expansion

Logistic curve model reflects the change of Q in time [7-8]. Its basic form is:

$$\frac{dz}{dt} = \alpha z\left(1 - \frac{z}{W}\right) \tag{1}$$

In formula (1), z is the parameter of the biota with growth characteristics to be analyzed, W is the critical point for the growth of the biota, α is the natural growth rate of the biota, and t is the time variable.

By solving the differential equation of the Logistic model, the size of the initial biological population is obtained:

$$\begin{cases} z = \frac{W}{1+\beta e^{-\alpha t}} \\ \beta = \frac{W \cdot z_0}{W - z_0} \end{cases} \tag{2}$$

In formula (2), β is an integral constant, and z_0 is the initial number of a biological population.

According to the impact of the expansion of the installation business of each power industry, the evolution curves of new addition, capacity increase, capacity reduction, account cancellation and suspension are constructed respectively:

$$\begin{cases} \frac{dz_1}{dt} = \alpha_1 z_1\left(1 - \frac{z_1}{W_1}\right) \\ \frac{dz_2}{dt} = \alpha_2 z_2\left(1 - \frac{z_2}{W_2}\right) \\ \frac{dz_3}{dt} = \alpha_3 z_3\left(1 - \frac{z_3}{W_3}\right) \\ \frac{dz_4}{dt} = \alpha_4 z_4\left(1 - \frac{z_4}{W_4}\right) \\ \frac{dz_5}{dt} = \alpha_5 z_5\left(1 - \frac{z_5}{W_5}\right) \end{cases} \tag{3}$$

In formula (3), z_1, z_2, z_3, z_4, z_5 represents the new, capacity increase, capacity reduction, account cancellation, and suspension of the expanded installation business of the power industry respectively; W_1, W_2, W_3, W_4, W_5 represents the evolution threshold of the impact of the new, capacity increase, capacity reduction, account cancellation, and suspension of the expanded installation business of each power industry respectively; $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ represents the inherent growth rate of the new, capacity increase, capacity reduction, account cancellation, and suspension of the expanded installation business of the power industry respectively.

Various growth curves can be obtained by solving differential equations:

$$\begin{cases} z_1 = \frac{W_1}{1+\beta_1 e^{-\alpha_1 t}} \beta_1 = \frac{W_1 \cdot z_{1_0}}{W_1 - z_{1_0}} \\ z_2 = \frac{W_2}{1+\beta_2 e^{-\alpha_2 t}} \beta_2 = \frac{W_2 \cdot z_{2_0}}{W_2 - z_{2_0}} \\ z_3 = \frac{W_3}{1+\beta_3 e^{-\alpha_3 t}} \beta_3 = \frac{W_3 \cdot z_{3_0}}{W_3 - z_{3_0}} \\ z_4 = \frac{W_4}{1+\beta_4 e^{-\alpha_4 t}} \beta_4 = \frac{W_4 \cdot z_{4_0}}{W_4 - z_{4_0}} \\ z_5 = \frac{W_5}{1+\beta_5 e^{-\alpha_5 t}} \beta_5 = \frac{W_5 \cdot z_{5_0}}{W_5 - z_{5_0}} \end{cases} \quad (4)$$

In formula (4), $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ is the integral constant, and $z_{1_0}, z_{2_0}, z_{3_0}, z_{4_0}, z_{5_0}$ is the value of new increase, capacity increase, capacity reduction, account cancellation, and suspension in the initial stage of evolution facing the impact of power industry expansion.

2.2 Analysis of the evolutionary life cycle phase facing the impact of power industry expansion

According to TICHY's life cycle model, its evolutionary life cycle is divided into incubation period, growth and development period, high-speed development period, maturity period and decline period. Five characteristic factors are selected to reflect the impact of power industry expansion on each stage of the life cycle, as shown in Table 1.

Table 1: Characteristic mode of power industry expansion affecting each stage of life cycle

Characteristic factors	Incubation period	Growth and development period	High speed development period	Mature period	Recession period
New increase	Relatively low	Relatively high	Relatively high	Very high	Commonly
Capacity increase	Commonly	Relatively high	Relatively high	Very high	Relatively low
Capacity reduction	Commonly	Relatively high	Relatively high	Very high	Very high
Account cancellation	Relatively high	Very high	Relatively high	Relatively high	Very high
Suspension	Commonly	Very high	Very high	Very high	Commonly

2.3 Fuzzy set description of characteristics at each stage of the life cycle for the impact of power industry expansion

The fuzzy set [9-10] is used to describe the language assessment with fuzziness in Table 1. First of all, experts will score according to different characteristics of power industry expansion. The higher the score, the stronger the representative ability; Then, using the concept of membership, the language descriptions in the 10 point scale are classified accordingly. In the evaluation language, the membership degree c of Cauchy distribution is "relatively low", "average" and "relatively high":

$$A(c) = \frac{1}{1+\chi(c-\chi)^{\delta}} \quad (5)$$

In formula (5), χ >0 and δ are even numbers, and χ is real numbers.

On this basis, the membership degree of semi Cauchy distribution is used to express the "very low" and "very high" membership degrees of score c in the evaluation language:

$$A(c) = \begin{cases} 1, c \geq \chi \\ \frac{1}{1+\chi(c-\chi)^{\delta}}, c < \chi \end{cases} \quad (6)$$

According to the actual situation, the specific definitions are as follows:

$$\begin{gathered} \mu_{\text{Very low}}(c) = \begin{cases} 1(c \leq 2) \\ [1 + ((c-2)/2)^2]^{-1}(c > 2) \end{cases} \\ \mu_{\text{Relatively low}}(c) = [1 + ((c-3.5)/2)^2]^{-1} \\ \mu_{\text{Commonly}}(c) = [1 + ((c-5)/2)^2]^{-1} \\ \mu_{\text{Relatively high}}(c) = [1 + ((c-6.5)/2)^2]^{-1} \\ \mu_{\text{Very high}}(c) = \begin{cases} 1(c \geq 8) \\ [1 + ((c-8)/2)^2]^{-1}(c < 8) \end{cases} \end{gathered} \quad (7)$$

3 LIFE CYCLE DECISION MODEL BASED ON FUZZY CLOSENESS

3.1 Determining fuzzy sets

In order to determine the life cycle of the impact of power enterprise expansion, suppose R is the set of the above five characteristic indexes, expressed in $R = \{r_1, \dots, r_5\}$. Suppose Y is a set of language variables represented by $Y = \{y_1, \dots, y_5\}$, that is, $Y = \{$ Very low, Relatively low, Commonly, Relatively high, Very high $\}$. Take U as the five stages of a life cycle and express it as $U = \{u_1, \dots, u_5\}$, that is, $U = \left\{ \begin{matrix} \text{Incubation period, Growth and development period,} \\ \text{High speed development period, mature period, mature period} \end{matrix} \right\}$.

3.2 Determination of fuzzy relation matrix

When the final life cycle determination is completed, the five evaluation indicators must be associated with the five life cycles, that is, the relationship of $R \rightarrow U$.

First, use formula (7) to determine the relationship between expert scores and language variables, that is, to determine the relationship between $R \rightarrow Y$, which can be taken as a fuzzy subset $s_i = (s_{1i}, s_{2i}, \dots, s_{5i})^T$ on the universe Y by the single objective $r_1 \in R$ of the decision object, and obtain a fuzzy matrix S on $R \times U$.

Then, according to the relationship between the language variable and its life cycle as shown in Table 1, namely $Y \rightarrow U$, $R \rightarrow U$ is determined, that is, the single objective $r_1 \in R$ of the decision object is taken as a fuzzy subset $d_i = (d_{1i}, d_{2i}, \dots, d_{5i})^T$ on the universe U, thus determining a fuzzy matrix D on $R \times U$.

3.3 Determine the life cycle judgment model

After determining the fuzzy discriminant matrix D, fuzzy discriminant is applied to multiple targets by using fuzzy closeness. First, the feature fuzzy subset is introduced, which is composed of feature function and fuzzy subset. The feature fuzzy subset can be obtained by deducing the feature function:

$$F_i = \{\langle f_1, 0.2\rangle, \langle f_2, 0.3\rangle, \langle f_3, 0.8\rangle\} \tag{8}$$

In formula (8), f_1, f_2 and f_3 are the elements in the feature fuzzy subset, and 0.2, 0.3 and 0.8 are the membership degrees of the corresponding elements in the set.

The definition of asymmetric closeness is introduced:

$$P(N, M) = 1 - \frac{2}{p(p+1)} \sum_{k=1}^{n} |\varepsilon_N(\phi_K) - \varepsilon_M(\phi_K)|_k \tag{9}$$

In the asymmetric approach degree $P(d_i, F_j)$ between single objective evaluation $d_i = (i = 1,2, \dots, 5)$ and feature fuzzy subset $F_j = (j = 1,2, \dots, 5)$, it is expressed as follows:

$$B_j = (b_{1i}, b_{2i}, \dots, b_{5i})^T = \left(P(d_i, F_1), P(d_i, F_2), \dots, P(d_i, F_5)\right)^T \tag{10}$$

Then the decision matrix under multi-objective $R = \{r_1, \dots, r_5\}$ is:

$$B = \left(B_{ij}\right)_{5\times 5} = (B_1, B_2, \dots, B_5) \tag{11}$$

As reference levels L^+ and L^-, such that:

$$L^+ = (L_1^+, I_2^+, \dots, I_5^+) = \left(\max_{j=1-5} P(d_1, F_j), \max_{j=1-5} P(d_2, F_j), \dots, \max_{j=1-5} P(d_5, F_j)\right) \tag{12}$$

$$L^- = (L^-{}_1, L^-{}_2, \dots, L^-{}_5) = \left(\max_{j=1-5} P(d_1, F_j), \max_{j=1-5} P(d_2, F_j), \dots, \max_{j=1-5} P(d_5, F_j)\right) \tag{13}$$

The benchmark level L^+ defined by formula (12) is a virtual evaluation level, which represents the best level to judge the decision object as L^+ under each objective. Similarly, the virtual level L^- defined by formula (13) represents the most inappropriate negative ideal level for judging the decision object as L^- under each objective.

In order to obtain the judgment results of multiple objectives, the relationship between each evaluation level in evaluation level L and ideal and negative values must be compared and recorded as follows:

$$L_i = (L_1^+, L_2^+, \dots, L_5^+) = \left(P(d_1, F_j), P(d_2, F_j), \dots, P(d_5, F_j)\right) \tag{14}$$

The vector determined by formula (14), in fact, is to judge whether the decision object is close to the i evaluation level under multiple objectives. Obviously, the closer the relationship between L_i and L^+ and the farther away from L^-, the higher the evaluation level of judging the decision goal as i; Otherwise, the judgment as a i grade assessment is not appropriate.

Compare the differences between L_i, L^+ and L^- and their similarity, which can be measured by symmetrical approximation, for example, first:

$$\delta(L^+, L_i) = \sum_{k=1}^{5} \mu_{L_i}(\varepsilon_k) / \sum_{k=1}^{5} \mu_L(\varepsilon_k) \tag{15}$$

$$\delta(L^-, L_i) = \sum_{k=1}^{5} \mu_{L^-}(\varepsilon_k) / \sum_{k=1}^{5} \mu_{L_i}(\varepsilon_k) \tag{16}$$

Calculate $\delta(L^+, L_i)/\delta(L^-, L_i)$ again if:

$$\delta(L^+, L_i)/\delta(L^-, L_i) = \max_{j=1-5}\left(\delta(L^+, L_i)/\delta(L^-, L_i)\right) \tag{17}$$

When there are multiple objectives, the decision object is determined as L_p level.

Through the above steps, the establishment of life cycle judgment model for the impact of power industry expansion is realized, the detailed construction process is shown in Figure 1.

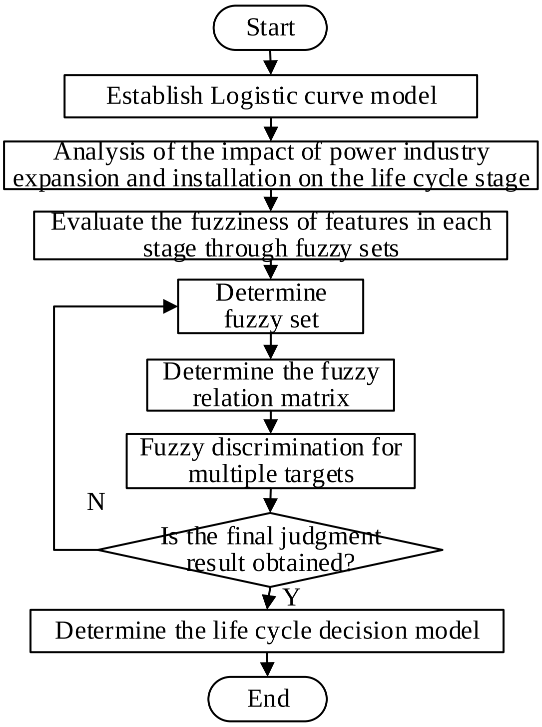

Figure 1: Flow chart of life cycle judgment model construction for the impact of power industry expansion

Through the above contents, the accuracy and efficiency of the judgment model can be improved.

4 EXPERIMENTAL ANALYSIS

In order to verify the validity of the life cycle judgment model for the impact of power industry expansion, the design model, the Reference [1] (Arshad, 2021) model and the Reference [8] (Wei, 2021) model are used for experimental testing. The test environment is shown in Table 2.

Table 2: Test environment

Operating environment	Configure	Parameter
Hardware environment	CPU	Intel(R) Core(TM) i5-9400
	Frequency	2.90GHz
	GPU	Mali-200
Software environment	Operating system	Windows 10
	Edition	18362.1082 Professional Edition
	Digit	64bit
	Analog software language	APDL

4.1 Analysis of judgment effect

When conducting life cycle judgment for the impact of power industry expansion in a region, the scoring order of the five characteristic indicators is $R = \{6,5,7,6,8\}$, $Y = \{$ Very low, Relatively low, Commonly,Relatively high, Very high $\}$ is the set of language variables, and $U = \left\{\begin{matrix} \text{Incubation period, Growth and development period,} \\ \text{High speed development period, mature period, mature period} \end{matrix}\right\}$ is the set of life cycle assessment. According to formulas (15) and (16), the judgment results of different stages and different models are calculated, as shown in Table 3.

Table 3: Judgment results of different models

Different stages	Judgment results of different models		
	The design model	The Reference [8] (Wei, 2021) model	The Reference [1] (Arshad, 2021) model
Phase 1	1.0344	1.3624	1.4213
Phase 2	1.3467	1.0198	1.5362
Phase 3	1.5881	1.2533	1.3325
Phase 4	1.1125	1.4521	1.0632
Phase 5	0.7542	1.0211	0.8921

Since the third stage of the design model is 1.5881, it can be judged from formula (17) that, like direct observation, the impact of power industry expansion is in the third stage of the life cycle, namely the high-speed development period. It can be seen from this that the model can effectively determine the life cycle stage of the impact of power industry expansion, and accurately measure the contribution of industry expansion to electricity, and the judgment effect is the best. However, the Reference [1] (Arshad, 2021) model and the Reference [8]

(Wei, 2021) model have deviations from the direct observation results, and the judgment effect needs to be further improved.

4.2 Judgment performance analysis

Take the accuracy rate as the judgment index to test the judgment performance of different methods in 10 experiments. The higher the accuracy rate, the better the judgment performance of the model. The test results are shown in Figure 2.

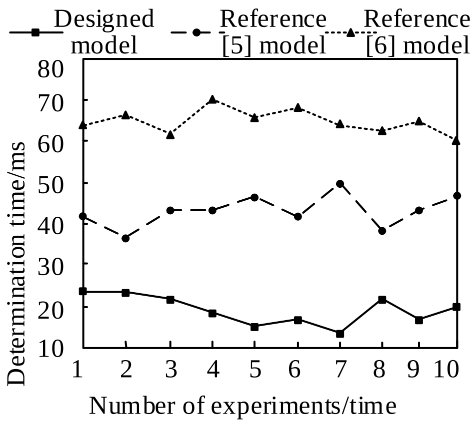

Figure 2: Determination accuracy of different models

As shown in Figure 2, the judgment accuracy of the design model is higher, and its judgment accuracy is always higher than 90%, with good judgment performance. The judgment accuracy of the Reference [1] (Arshad, 2021) model and the Reference [8] (Wei, 2021) model are between 81%~84% and 84%~87%, respectively. Although these two models also have high accuracy, they are lower than the design model, and the maximum accuracy is not more than 90%. The judgment performance needs to be further strengthened.

5 CONCLUSION

In order to accurately measure the impact of industry expansion and installation on electricity consumption and clarify the life cycle of power industry expansion and installation, this paper constructs a life cycle assessment model for the impact of power industry expansion. Build an evolutionary curve model for the impact of power industry expansion, analyze the stages of the evolutionary life cycle, and describe the characteristics of each stage of the life cycle. By determining the fuzzy set, fuzzy relation matrix and life cycle decision model, the life cycle decision oriented to the impact of power industry expansion is realized. The experimental results show that the judgment results of the design model are basically consistent with the direct observation results, and the judgment accuracy is always higher than 90%, the judgment time is less than 25ms, which can effectively determine the life cycle stage of the impact of power industry expansion, and accurately measure the contribution of industry expansion to electricity, the work quality of the power supply company has been improved.

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