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Article

Evaluation Indicators Screening Based on Interval Estimation Model--Taking Location of Production and Service Facilities of Company A as an Example

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Abstract: With the focus of great concern of the sustainable development, its evaluation system has become an important operational strategy and practical values. For the purpose of obtaining the stronger indicators and the larger contribution ones, evaluation indicators screening is carried out using interval estimation model, which takes location of production and service facilities of company A as an example. And the weight value of each indicator is further explored, which can provide an direction of decision-making. The result shows that this screening method provides a more scientific evaluation method for enterprise location, decision-making basis for sustainable development of enterprises, and a solid foundation for the construction of the post-evaluation system. The present work implies that this screening method is affected, to different degrees, by the ability, knowledge reserve of the evaluators, which should be more systematic and standardized, and the concept of sustainable development should be strengthened.

Keywords: location; screening; interval estimation model;

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1. **Introduction**

Evaluation means that through quantitative and non-quantitative measurement processes of the evaluation targets, the evaluators can reach a reliable and logical conclusion (Bao, 2018). However, when an evaluation system is set up for evaluation, there may exist redundant indicators under the condition of satisfying consistency test, which will affect the accuracy and scientificity of the evaluation results. There are also indicators that can't meet the consistency requirements, the reason is that the contribution of indicators has been overwhelmed by the error of the system, the indicators won't contribute substantially to the

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evaluation. Hence, the indicators need to be screened.

At present, the commonly used qualitative screening methods are theoretical analysis and expert consultation. According to Fan et al. (2002), Lin et al. (2012) and Li et al. (2017), the subjectivity of this method is too strong, and the analysis results are not accurate. Lu & Jiang (2007), Liu (2005), and Mu et al. (2015) think the common methods of quantitative analysis include statistical analysis and Liu et al. (2004) and Lu & Zhang (2008) give the grey relational analysis, but these two methods require a large amount of sample data and have some limitations. Based on these points, this article applies the interval estimation analysis method based on qualitative and quantitative Analytic Hierarchy Process (AHP) to eliminate redundant indicators and indicators that contribute little, to screen the location of production and service facilities for further research, and establishes a reliable indicator system foundation for the later evaluation.

2. Description of Interval Estimation Model

AHP method is a combination of qualitative and quantitative decision analysis, it has been applied to program optimization, comprehensive evaluation, feasibility judgment and so on in many fields (Bao et al., 2016, Bao et al., 2017(94), and Bao et al., 2017(133)). The basic method of AHP based on interval estimation is that only the indicators contributing to decision objectives can be used as criteria for measuring alternatives (Gao et al., 2005, Zhong & Fu, 2012, Liu et al., 2012, Mao et al., 2007 and Wang, 2013). Because of the difference of knowledge, ability and information among the evaluators, there may be some errors in the scoring results (Sam et al., 1996). This is, if the importance of an indicator is small enough, or the contribution of that indicator has been obscured by systematic errors, it can't contribute substantially to system evaluation and should be eliminated (Bao, 2018, and Azadeh & Zadeh, 2016). And the model steps are built as follows:

Step1. To build the judgment matrix. To compare the relative importance between the established standard layer and the target layer with 1~9 scale method proposed by Professor Thomas (Thomas, 2005). And to build the judgment matrix at each level as $A_n = (a_{ij})_{n\times n}$.

Step2. To conduct the consistency test according to relative consistency indicator formula, where $CR = \frac{CI}{RI}$, $\lambda_{\max} = 1/n\sum_{i=1}^{n}(AW)/\omega_i$, $\lambda_{\max}$ is the maximum eigenvalue of judgment matrix, n is the order of a judgment matrix, RI is the mean random consistency indicator whose values are shown in **Table 1**.

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Table 1 *RI* Set Value

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

Step3. When $0 \le CR \le 0.1$, the judgment matrix has satisfactory consistency. The weight vector of the judgment matrix can be calculated as $W = [\omega_1, \omega_2 \ldots \omega_n]^T$ with Yaahp software, then the appropriate indicators selection weight ξ is selected to screen the indicators of this layer. (Normally, ξ is set as 0.05, if $W_i > \zeta$ means there are no weak indicators.)

Step4. When $CR > 0.1$, the judgment matrix can't meet the consistency requirement. The upper limit value ω_i^U and the lower limit value ω_i^L should be calculated according to interval estimation model, and the calculation should satisfy the following linear programming model (Takayama, 1998).

$$\max(\min)\omega_i$$
$$s.t.\begin{cases} \overline{A}W \le 0 \\ W = [\omega_1, \omega_2 \ldots \omega_n] > 0 \\ \omega_1 + \omega_2 + \ldots \omega_n = 1 \end{cases}$$

Step5. If the weight ω_i can satisfy $\omega_i^U \le \Delta_{\max}$,where $\Delta_{\max} \le \max_{1 \le i \le n}(\omega_i^U - \omega_i^L)$, then the contribution of this indicator has been masked by systematic error and should be eliminated.

3. Construction of Evaluation Indicators for Location of Production and Service Facilities

Location problems should be considered from a systematic point of view, because the whole production activity is a whole, it is impossible for enterprises to exist in isolation. Based on it, enterprises should consider not only suppliers but also customers, as well as product distribution (Chen & Ma, 2016).

In general, the factors to be considered in location problems can be divided into four categories: economic factors, political factors, social factors and natural factors (Chen & Ma, 2016). **Table 2** is designed for providing a framework for the implementation of location problems of production and service facilities.

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Table 2 Framework of Evaluation Indicators System for Location of Production and Service Facilities

First-grade Indicator	Second-grade Indicator
Economic factors	Transport conditions and cost
	Labor accessibility and cost
	Energy accessibility and cost
	Site conditions and cost
Political factors	Political situation
	Legal system
	Tax revenue
Social factors	Living habits of residents
	Cultural and educational level
	Religious belief
	Living standard
Natural factors	Climatic conditions
	Water resources situation

From a systematic point of view, location decision should minimize the cost of the whole production distribution chain. From the analysis of the actual situation, there are many constraints on the location of enterprises, such as the impact of the same type of enterprises in pre-location, etc. With the rapid development of production and economy, China has been paying more and more attention to the viewpoints of sustainable development such as environmental governance, consumption and emission, which play an important role in the location of production and service facilities. In some areas, even these sustainable development indicators are implemented by one-vote veto system (Chen & Ma, 2016).

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4. Evaluation Indicators Screening for Location of Production and Service Facilities--a Case Study of Company A

Company A is located in the south of China and its climate is between 15 and 37 degrees centigrade. It is a manufacturer and operator of chemicals, which is one of the largest chemical enterprises in the world with a scale of nearly 1,000 people. Considering the low cost of labor, raw materials and the saving of transportation costs, the company plans to build a new production and processing plant in B city, so the location becomes the first issue.

4.1Establishment of Preliminary Evaluation Indicator System for Location

Considering its location framework and all the specific conditions that the enterprise will face, five senior evaluators, including one enterprise internal auditor, one enterprise external auditor, one enterprise senior manager and two members of trade associations in B City, adopted brainstorming method to evaluate the location factors. The results of the evaluation indicator system are shown in **Table 3**.

Table 3 Preliminary Evaluation Indicator System for Location of Production and Service Facilities

First-grade Indicator	Second-grade Indicator
U_1 Economic factors	U_{11} Close to the market
	U_{12} Close to the port
	U_{13} Easy to transport raw materials
	U_{14} Rental fee
	U_{15} Local economic level
U_2 Political factors	U_{21} Local government stability
	U_{22} Cooperation with local governments
	U_{23} Perfect legal system of local government
	U_{24} Reasonable tax burden of the local government
	U_{25} Local government's attitudes towards chemical enterprises
U_3 Social factors	U_{31} Living habits of residents
	U_{32} Cultural and educational level
	U_{33} Religious belief

	U_{34} Living standard
	U_{35} Labor resources
	U_{41} Adequate infrastructure nearby
	U_{42} Water resources situation
U_4 Natural factors	U_{43} Moderate climatic conditions
	U_{44} Convenient treatment of pollutants
	U_{45} Emission Compliance

4.2 The indicator weight and consistency test of $W_{U_1-U_4}$

5 selected evaluators were invited to judge the importance of the indicators with AHP method. According to step 2, ω_i, $A\omega_i$ and $\frac{A\omega_i}{\omega_i}$ of first-grade indicators can be calculated as shown follows.

Table 4 Calculation Results of First-grade Indicators

	U_1	U_2	U_3	U_4	W_i	AW_i	AW_i / W_i	$CI=(\lambda-n)/(n-1)$	$CR=CI/RI$
U_1	1	3	5	4	0.536	2.213	4.129		
U_2	1/3	1	3	3	0.253	1.064	4.197	0.063	0.071
U_3	1/5	1/3	1	1/3	0.074	0.311	4.188		
U_4	1/4	1/3	3	1	0.136	0.578	4.242		

From **Table 4**, it can be concluded that $W_{U_1-U_4}=[0.536, 0.253, 0.074, 0.136]$, $CR=0.071<0.1$, the result has passed the consistency test. Let indicator selection weight $\xi=0.05$, $\omega_{U_1-U_4}>0.05$, so, no weak indicators can be eliminated.

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4.3 The indicator weight and consistency test of $W_{U_{11}-U_{15}}$

In the same way, as shown in **Table 5**, $W_{U_{11}-U_{15}} = [0.323, 0.323, 0.208, 0.104, 0.043]$, $CR = 0.091 < 0.1$, the result has passed the consistency test, but $\omega_{U_{15}} < 0.05$, the result indicates it is a weak indicator which should be eliminated.

Table 5 Calculation Results of $W_{U11-U15}$

	U_{11}	U_{12}	U_{13}	U_{14}	U_{15}	W_i	AW_i	AW_i/W_i	CI=（λ-n）/(n-1)	CR=CI/RI
U_{11}	1	3	2	4	8	0.323	2.464	7.637		
U_{12}	1/3	1	3	3	8	0.323	1.708	5.292		
U_{13}	1/2	1/3	1	2	8	0.208	1.027	4.937	0.111	0.091
U_{14}	1/4	1/3	1/2	1	2	0.104	0.482	4.632		
U_{15}	1/8	1/8	1/8	1/2	1	0.043	0.201	4.713		

4.4 The indicator weight and consistency test of $W_{U_{21}-U_{25}}$, $W_{U_{21}-U_{25}}$, *and* $W_{U_{21}-U_{25}}$

Using the same method, the weights, *CR*, weak indicators, and substantive contributions of U_{21-25}, U_{31-35} and U_{41-45} can be calculated as shown in **Table 6**.

Table 6 Calculation Results of $W_{U21-U45}$ and CR

	W_i	CR	Weak Indicator	Substantive Contribution
U_{21}-U_{25}	0.045,0.213,0.304,0.203,0.235	0.076	U_{21}	/
U_{31}-U_{35}	0.124,1.265,0.037,0.353,0.221	0.064	U_{33}	/
U_{41}-U_{45}	0.320,0.289,0.202,0.107,0.071	0.139	/	no

4.5 The calculation of interval estimation model

Concluded from **Table 6**, $W_{U21} = 0.045 < 0.05$ and $W_{U33} = 0.037 < 0.05$ indicate that they are weak indicators, and should be eliminated. $CR_{U41-U45}=0.139 > 0.1$ indicates that the result hasn't passed the consistency test, interval estimation model should be adopted to calculate the

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upper and lower limit values of each indicator with LINGO 11.0 software. The results are shown in **Table 7**.

Table 7 Upper and Lower Limit Values and Weight Values

	U_{41}	U_{42}	U_{43}	U_{44}	U_{45}
Upper Limit Value	0.180	0.129	0.049	0.116	0.139
Lower Limit Value	0.066	0.109	0.039	0.109	0.118
Δ_i	0.114	0.020	0.010	0.005	0.021
w_i	0.320	0.289	0.202	0.107	0.071

It can be concluded from **Table 7** that only $\omega_{43}{}^{U} < \Delta_{\max}$, that is, $0.049 < 0.114$, the contribution of the U_{43} has been covered by systematic error, and it will not make substantive contribution to the system evaluation, and should be eliminated.

4.6 Evaluation indicator system after screening and the result

The eliminated indicators from Table 4 to Table 7 include U_{15}(Local economic level), U_{21}(Local government stability), U_{33}(Religious belief), and U_{43}(Moderate climatic conditions), and the remaining ones still need screening using the same method. The consistency test of U_{11}-U_{45} has well satisfied the format $CR<0.1$, all the weight values of the indicators are greater than 0.05, and the results imply that the final indicator system is effective, which is shown in **Table 8**.

Table 8 Evaluation indicator system with weight value after screening for Location of Production and Service Facilities

First-grade Indicator	Second-grade Indicator
U_1 Economic factors 0.536	U_{11} Close to the market 0.323
	U_{12} Close to the port 0.323
	U_{13} Easy to transport raw materials 0.208
	U_{14} Rental fee 0.146
U_2 Political factors 0.253	U_{22} Cooperation with local governments 0.213
	U_{23} Perfect legal system of local government 0.346
	U_{24} Reasonable tax burden of the local government 0.208

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	U_{25} Local government's attitudes towards chemical enterprises 0.233
U_3 Social factors 0.074	U_{31} Living habits of residents 0.251
	U_{32} Cultural and educational level 0.215
	U_{34} Living standard 0.208
	U_{35} Labor resources 0.326
U_4 Natural factors 0.136	U_{41} Adequate infrastructure nearby 0.323
	U_{42} Water resources situation 0.301
	U_{44} Convenient treatment of pollutants 0.208
	U_{45} Emission Compliance 0.168

In addition, in order to verify the accuracy of the results, two members of trade associations in B City were asked why U_{15}, U_{21}, U_{33}, and U_{43} were screened. The reason is that the correlation degree between the screened indicators and the location is not high. In other words, they are not the key indicators for the location. From this perspective, this indicator screening method is scientific and feasible.

5. Suggestion and Conclusion

This study provides a more scientific method for enterprise location by eliminating weak indicators and indicators with little contribution, and the establishment of indicator weight also provides a decision direction for enterprise internal management. Importantly, this screening method improves the accuracy of the evaluation system, lays a good foundation for the later evaluation system, and is a methodological trend.

But inevitably this method is still a subjective evaluation, the results will be affected by the ability, knowledge reserve of the evaluators. Different evaluators may have different results for the same indicator evaluation. At the same time, from the evaluation results analysis, the weight value of economic factors is 3.94 times than that of natural factors. And, the weights of U_{44} (Convenient discharge of pollutants) and U_{45}(Emission compliance) are also the lowest under the first-level indicator of natural factors. From the perspective of sustainable development, this behavior of enterprises will affect the balanced development of economy, society and environment.

Faced with this dilemma, how to reduce the effect of the subjective factors of the evaluators and how to improve the attention of enterprise policymakers to sustainable development are both challenges.

For future work, this screening method should be more systematic and standardized, and at any time, for any enterprise, the concept of sustainable development is indispensable.

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Rererences

1. Azadeh, A.; Zadeh, S.A. An integrated fuzzy analytic hierarchy process and fuzzy multiple-criteria decision-making simulation approach for maintenance policy selection. *Simulation*. 2016, 1, 3–18.
2. Bao. J.D. Application of Statistical Methods on Occupational Health and Safety Management in the Mining Industry in Ezhou City, China. *Luleå University of Technology Press*. 2018.
3. Bao. J.D., Johansson.J., and Zhang. J.D. Comprehensive Evaluation on Employee Satisfaction of Mine Occupational Health and Safety Management System based on Improved AHP and 2-tuple Linguistic Information. *Sustainability*. 2017, 9(1), 133.
4. Bao. J.D., Johansson.J., and Zhang. J.D. Occupational Disease Assessment of Mine Industry Occupational Health and Safety Management System based on FMEA and Improved AHP Model. *Sustainability*. 2017, 9(1), 94.
5. Bao. J.D., Zhang. J.D., Li. F., Liu. C.Y., Shi. S.P. Social benefits of the mine occupational health and safety management systems of mines in China and Sweden based on a fuzzy analytic hierarchy process: A comparative study. *Journal of Intelligent & Fuzzy Systems*. 2016,31(6), 3113-3120.
6. Chen. R.Q., Ma. S.H. Production and Operation Management (Fourth Edition). *Higher Education Press*. 2016
7. Fan. B.N., Shan.S.T., Lu.C.S. Research on screening methods of evaluation index of urban technological innovation capability. *Scientific Research*. 2002, 20(6), 663-668.
8. Gao.J., Sun.L.Y., Li.M.Y. Interval estimation: a method of AHP indicator screening. *System Engineering Theory and Practice*. 2005,25(10),73-77.
9. Li. X., Tian.X.H., Du.W.H. Screening of drought resistance indexes of forage type triticale seedlings. *Pratacultural Science*. 2017,34(03),539-546.
10. Lin.L.M., Zhang.J.C. Liu.J.X., Long.P.Y., Tang.X. Shale gas exploration, target layer, optimization. *Earth Science Frontiers*. 2012,19(03), 259-263.
11. Liu.R.H., Yu.B., Jin.Z. Index selection of subway construction safety risk evaluation based on interval estimation. *Forecast*. 2012,31(02),62-66.
12. Liu.S.F., Dang.Y.G., Fang.Z.G. Grey system theory and its application. *Science Press*. 2004.
13. Lu.J.L.,Zhang.Z.G. Study on Markov residual correction model of mid long term power load rolling prediction based on grey relational index selection in BP neural network. *East China Electric Power*. 2008,9,15-18.

14. Lu.N., Jiang.L.N. Study on index selection of real estate market prosperity in Xi'an. *Journal of Chang'an University*. 2007,9(3),57-60.

15. Liu.X. Research on evaluation indicator system of enterprise comprehensive ability based on circular economy. *Nanjing University of Technology*. 2005.

16. Mao.H.B., Zhang.F.M., Zou.W.G. A method of combination weighting for multiple attribute decision making based on interval estimation. *System Engineering Theory and Practice*. 2007,(06),86-92.

17. Mu.Y.Z., Lu.Z.X., Qiao.Y., Wang.Y., Huang.H., Zhou.Q.Y., Han.J.H. Comprehensive evaluation index system of power grid safety and benefit based on multi operator analytic hierarchy process fuzzy evaluation. *Power Grid Technology*. 2015,39(01),23-28.

18. Sam Skog.P.O., Bjorkman.J. Herbst.J. The implementation of process control of LKAB company in Kiruna - ore pellet plant. *Foreign Metal Mines*. 1996,3,37-43.

19. Takayama. I. Problem in AHP and ANP. Communications of the Operations. *Research Society of Japan*.1998,43,100-104.

20. Thomas, L.S. Making and validating complex decisions with the AHP/ANP. *J. Syst. Sci. Syst. Eng.* 2005, 14,1–36.

21. Wang.J., Tang.P.C., He.J.P. Selection of factors influencing fuel tax pricing in China based on AHP and interval estimation. *Journal of Wuhan University of Technology (Traffic Science and Engineering)*. 2013,37(02),326-329.

22. Zhong.X.W., Fu.H.Y. Comprehensive evaluation method based on interval estimation and its application. *Practice and Understanding of Mathematics*. 2012,42(01),74-79.