The Model of Project Site Selection of Industrial Plant Based on Matter Element Analysis

Qi Zhang[1], Qiuping Wang[1], Siping Lin[2], Weifeng Li[2]

[1]School of Civil Engineering, Xi'an Univ. of Arch. & Tech.Xi'an, China
[2]China Coal Xi'an Desigineering CO., LTD. Xi'an, China
zhangqi-xauat@163.com

Abstract-**After a brief introduction to the project site selection of industrial plant (PSSIP), a new model of PSSIP, with which the comparison between elements in the feasible set and ideal references out of the feasible set can be achieved, is proposed according to the Extenics and its matter element (ME) theories founded by a Chinese scholar Wen Cai. Firstly, the matter element of feasible schemes (MEFS) is not only established but also standardized by the eigenvalue of different evaluating indexes in this model. Secondly, the matter element of ideal references (MEIR) is established with the help of the value range analysis of all the eigenvalues of each MEFS and then the degree of nearness between MEFS and MEIR can be detected by Euclid Distance. Thirdly, in order to modify the model which can hardly embody the importance levels of different evaluating indexes, the compound weight considering both the subjective weight with priority judgment method and the objective weight with entropy method is raised in this paper. Fourthly, the comprehensive degree of nearness between MEFS and MEIR gained by the improved calculation of Euclid Distance with the compound weight can be used as the criterion to select industrial site. Finally, with a case study of a coal preparation plant in Shaanxi, China, it is suggested that the model of PSSIP based on ME analysis is practical and exercisable and its result is believable.**

Keywords-PSSIP; MEFS; MEIR; comprehensive degree of nearness; compound weight; case study

I. ESSENTIALS OF THE PROJECT SITE SELECTION OF INDUSTRIAL PLANT

In the process of industrialization, a large number of basic industrial projects have been proposed and put into practice. And the spatial form in which these projects exist and develop is the industrial plant.

The site selection of industrial plant is a process of spatial orientation, in which all sorts of relevant technical and economic analyses will be given spatial significance [1]. But in terms of different scales of space range, the mission requirements and the depth of the contents of the site selection of industrial plant are much different. Generally speaking, the site selection of industrial plant has two space dimensions: First, the planning site selection. The region of space that is considered covers tens of thousands of square kilometers or larger areas, the analysis is mainly based on the economic and social development requirements, local resources, institution superiority and others. Second, the project site selection. The region of space that is considered covers thousands of square kilometers or smaller areas, the analysis is mainly based on the construction condition, operation safety, external contact and others.

This paper discusses the method of the project site selection of industrial plant (referred to as "the project site selection" below), based on feasibility study and prophase planning of the specific industrial project.

The project site selection mostly works by way of system comprehensive evaluation [2]. That is, first of all, to seek the candidate set of industrial plant by engineering experience; then, by establishing an evaluation model, analyze comprehensively each index (including qualitative and quantitative index) of each scheme of the candidate set and get the comprehensive evaluation value of each scheme; finally, pick the best scheme as the industrial plant.

It's worth noting that, the reliability and practicability of evaluation model will directly affect the utility of project site selection method. The most common comprehensive evaluation methods, such as the principal component analysis, analytic hierarchy process (*AHP*) [3], and the fuzzy comprehensive evaluation method [4], use the evaluation model, which mostly uses the method of comparing the industrial plant of feasible schemes with each other, rather than comparing each feasible scheme with the ideal reference that does not belong to the feasible schemes. For this reason, with the above methods, the project site selection work will be vulnerable to subjective matter, and also the project site selection conclusion will be likely to produce deviation.

In order to establish a more objective and comprehensive evaluation model of project site selection, this paper, according to matter element (*ME*) theories of the Extenics, describes alternative schemes of project site selection as matter element of feasible schemes (*MEFS*), uses for reference the thinking of ideal point method[5] in operations research to structure matter element of ideal references (*MEIR*) that do not belong to the feasible schemes, and then achieves the purpose of identifying the industrial plant's quality by measuring the degree of nearness between *MEFS* and *MEIR*. This *ME* analysis model of project site selection provides a new perspective for the industrial plant scheme optimization.

II. ME ANALYSIS MODEL OF THE PROJECT SITE SELECTION OF INDUSTRIAL PLANT

A. ME and MEFS

According to the extenics and its extenics engineering theories [6], founded by Wen Cai, a scholar from Guangdong University of Technology of China, *ME* is the basic element to describe the thing. It is a trio made up of the thing *M*, the characteristic of the thing *C*, and the characteristic value *V*. The ME is represented by formula (1).

$$ME = \begin{bmatrix} & M \\ C & V \end{bmatrix} \qquad (1)$$

Things have n characteristics (n >1), say that ME is n dimension ME.

In the engineering practice of project site selection, m alternative schemes could be separately considered as the thing M_i (i=1~ m), and n indexes for evaluating scheme could be considered the characteristic C_j (j=1~ n), then the index value is the characteristic value V_{ji}. So MEFS of the project site selection is represented by formula (2).

$$MEFS_i = \begin{bmatrix} & Mi \\ C_1 & V_{1i} \\ C_2 & V_{2i} \\ ... & ... \\ C_n & V_{ni} \end{bmatrix} \quad (i = 1 \sim m) \qquad (2)$$

B. MEFS Standardization

In the engineering practice of project site selection, dimensions of different evaluation indexes may be quite different, so it is difficult to compare different evaluation indexes with each other. The way to solve this problem is to standardize the characteristic value V_{ji} of *MEFS* [7]. After standardization, get the characteristics value SV_{ji} of C_j index by calculating formula (3), formula (4).

For benefit index (the bigger the better)

$$SV_{ji} = \frac{V_{ji} - \min V_{ji}}{\max V_{ji} - \min V_{ji}} \quad (i = 1 \sim m) \qquad (3)$$

For cost index (the smaller the better)

$$SV_{ji} = \frac{\max V_{ji} - V_{ji}}{\max V_{ji} - \min V_{ji}} \quad (i = 1 \sim m) \qquad (4)$$

Through the standardization, get each *MEFS* by formula (5)

$$MEFS_i = \begin{bmatrix} & Mi \\ C_1 & SV_{1i} \\ C_2 & SV_{2i} \\ ... & ... \\ C_n & SV_{ni} \end{bmatrix} \quad (i = 1 \sim m) \qquad (5)$$

Among it， $SV_{ji} \in [0,1]$.

C. MEIR

Use $max\{SV_{ji}\}(i=1 \sim m)$ as C_j index value to structure positive matter element of ideal references $MEIR^P$, and use $min\{SV_{ji}\}(i=1 \sim m)$ as C_j index value to structure negative matter element of ideal references $MEIR^N$. Because the SV_{ji} is a standardized value, *MEIR* could be written as formula (6), and formula (7).

$$MEIR^P = \begin{bmatrix} & M^P \\ C_1 & 1 \\ C_2 & 1 \\ ... & ... \\ C_n & 1 \end{bmatrix} \quad (6) \qquad MEIR^N = \begin{bmatrix} & M^N \\ C_1 & 0 \\ C_2 & 0 \\ ... & ... \\ C_n & 0 \end{bmatrix} \quad (7)$$

The project site selection scheme represented by $MEIR^P$ and $MEIR^N$ may not exist in reality (If the $MEIR^P$ exists, the corresponding scheme would be the recommended scheme; if the $MEIR^N$ exists, and the corresponding scheme would be eliminated from feasible schemes). But considering the expansion of the set, it is feasible to add them separately to be the optimal scheme and the worst scheme of feasible schemes. For any $MEFS_i$, if it is nearer to $MEIR^P$ and farther from $MEIR^N$, the scheme will be more possible to be the recommended scheme.

D. Calculating Degree of Nearness

Degree of nearness between *MEFS* and $MEIR^P$ or between *MEFS* and $MEIR^N$ could be measured with Euclid Distance [8]. The bigger Euclid Distance is, the lower degree of nearness would be. Euclid Distance between the different *ME* could be calculated by formula (8), formula (9).

$$D_i^P = d(MEIR^P, MEFS_i) = (\sum_{j=1}^{n}(1 - SV_{ji})^2)^{\frac{1}{2}} \qquad (8)$$

$$D_i^N = d(MEIR^N, MEFS_i) = (\sum_{j=1}^{n}(0 - SV_{ji})^2)^{\frac{1}{2}} \qquad (9)$$

Meanwhile, it should be noted that, measuring the degree of nearness between *ME* by Euclid Distance directly means that the different characteristic indexes are equal, but it does not conform to the actual situation. Therefore, the different characteristic indexes of *ME* should be bestowed weight after analyzing their importance.

E. Calculating Weight

There are many studies about the methods of determining weight of system comprehensive evaluation. Currently, it is generally accepted [9] that the compound weight that is obtained by the method combining subjective weighting method and objective weighting method is more credible. Considering that, the judgment based on expert experience and the judgment based on the measured data are both of great significance, so this paper also uses the method which combines subjective weighting method and objective weighting method.

About objective weighting method, this paper uses entropy weighting method of information theory, which means that entropy weight will be regarded as objective weight. The calculation steps are [10]:

From information entropy:

$$H_j = -(\sum_{i=1}^{m} f_{ji} \ln f_{ji}) / \ln m \qquad (10)$$

Among it:

$$f_{ji} = (1+SV_{ji}) / \sum_{i=1}^{m}(1+SV_{ji}) \qquad (11)$$

Then get entropy weight:

$$w_j = (1-H_j)/(n-\sum_{j=1}^{n}H_j) \qquad (12)$$

About the subjective weighting method, the author does not think that the *AHP* commonly used is appropriate to the practice of determining the index weight in the project site selection. The reason is: there are too many characteristic indexes to be considered when evaluating the project site selection scheme (usually $n \geqslant 10$),even highly experienced experts can not determine the relative importance of any two schemes on a precise level between 1 and 9 definitively.

Therefore, this paper uses priority judgment method to determine the subjective weight. The basic idea is: the experts should make multiple comparisons of each characteristic index, then only make simple judgment on the relative merits of the results. There will be one of three possible outcomes after the priority judgment method: a) The first scheme is worth 0; b) The second scheme is important than the first one, the second is worth 1 point, the first scheme is worth 0; c) both equally important, each worth 1 point. Accumulate every characteristic index score to gain the total score P_j of C_j (j=1~n) item when comparison of all the characteristic indexes are completed. The subjective weight value of C_j item characteristic index can be calculated in line with the formula (13).

$$w'_j = P_j / \sum_{j=1}^{n} P_j \qquad (13)$$

Finally, according to the objective weight and subjective weight, calculate the compound weight W_j. Formula follows formula (14).

$$W_j = (w_j \cdot w'_j) / \sum_{j=1}^{n}(w_j \cdot w'_j) \qquad (14)$$

F. Calculating the Comprehensive Degree of Nearness

The formula (8) and (9) are amended by plugging the compound weights into the formula of Euclid distance when the compound weights of all characteristic indexes are identified. That is, consider the closeness degree of $MEFS_i$ and $MEIR^P$, $MEFS_i$ and $MEIR^N$ on the basis of the differences between each characteristic indexes. The optimized industrial site should follow the norm of extended space by which the further from $MEIR^P$ and closer to $MEIR^N$, the better it will be since the nearness will decrease with the growth of Euclid distance. In this rule, according to formula (15) it can be calculated that the comprehensive degree of nearness Z_i (i=1~m) of towards the positive and negative reference *ME*.

$$Z_i = \frac{(\sum_{j=1}^{n} W_j^2 (0-SV_{ji})^2)^{\frac{1}{2}}}{(\sum_{j=1}^{n} W_j^2 (0-SV_{ji})^2)^{\frac{1}{2}} + (\sum_{j=1}^{n} W_j^2 (1-SV_{ji})^2)^{\frac{1}{2}}} \qquad (15)$$

The bigger Z_i is, the closer to $MEIR^P$ $MEFS_i$ is. Meanwhile it's far away from $MEIR^N$, so the site selection can be done in accordance with the value of Z_i.

III. A CASE OF ME ANALYSIS MODEL

A. The Overview of an Actual Project

In order to improve the level of deep-processed coal resources and high added value of finished goods, a group mine's coal preparation plant project with an designed annual processing capacity of 3.00*Mt* was proposed. The site chosen was in a certain county of Shaanxi Province after the planning site selection.

Three optional schemes of the coal preparation plant sites on the county scale were identified after the preliminary qualitative analysis of the site selection. Through the quantitative comparison of these three schemes, the selection started with characteristic index as follows:

First of all, as lying in the pale of a coal mine region, the site of the coal preparation plant should avoid being located on the surface where coal resources exist underground as much as possible so that the jeopardy of mining collapse can be decreased and the efficiency of the exploitation of coal resources can be increased. Therefore, the value of protective coal pillars (C_1) is employed as the characteristic index to express this situation.

Secondly, a comparison of industrial site construction conditions can start from the following four indicators: land occupation area (C_2), resettlement population (C_3), land transfer rent (C_4), amount of earthwork (C_5).

Thirdly, whether the industrial site possesses well-conditioned transportation condition is one of the key factors which influence the realization of the coal preparation plant production capacity. In the evaluation of transportation condition, it is necessary to consider the coal from industrial site of the coal preparation plant transported to the national rail network after washing, and to consider the condition that raw coal out of the well transported to the coal preparation plant. Select the distance of the location of railway connection (C_6), the total length of the building belt conveyer (C_7) (the belt conveyors are built between all mines and the optional industrial sites) for the scheme comparison of two characteristic indexes.

Fourthly, water, electricity and other infrastructure are very important to the normal work of coal preparation plant. The washing technique, in particular, has a very high demand for drainage condition. The distance to high voltage substation (C_8), the distance to the junction of the water supply line(C_9),and the distance to wastewater treatment plant (C_{10}) are characteristic indexes to be considered.

Finally, because M_1, M_2, M_3 three schemes are in the same mining industrial site, their engineering geological conditions are similar, and the standard of flood control can be met, so these two aspects are no longer a separate characteristic index in the comparison and selection.

In summary, the evaluation indexes and their eigenvalues of 3 feasible schemes of a coal preparation plant are listed in table 1.

Tab.1 The Evaluating Indexes and Their Eigenvalues of Feasible Schemes of a Coal Preparation Plant

indexes	unit of measurement	schemes		
		M_1	M_2	M_3
C_1	Mt	1.05	1.39	2.12
C_2	ha	25	35	20
C_3	the number of people	520	130	50
C_4	￥ 10^4	4750	1975	1100
C_5	10^4 m^3	12	29	75
C_6	km	2.1	1.9	4.4
C_7	km	17.2	18.0	10.8
C_8	km	0.9	1.5	3.3
C_9	km	0.2	0.5	4.0
C_{10}	km	1.7	2.4	6.2

B. Determining the chart of the feasible ME

The characteristic indexes listed in table 1 are all cost types. Therefore, calculate the feasible ME of the three possible schemes according to the formula (2), (4) are:

$$MEFS_1=\begin{bmatrix} & \mathrm{M}_1 \\ \mathrm{C}_1 & 1.000 \\ \mathrm{C}_2 & 0.667 \\ \mathrm{C}_3 & 0.000 \\ \mathrm{C}_4 & 0.000 \\ \mathrm{C}_5 & 1.000 \\ \mathrm{C}_6 & 0.920 \\ \mathrm{C}_7 & 0.111 \\ \mathrm{C}_8 & 1.000 \\ \mathrm{C}_9 & 1.000 \\ \mathrm{C}_{10} & 1.000 \end{bmatrix} \quad MEFS_2=\begin{bmatrix} & \mathrm{M}_2 \\ \mathrm{C}_1 & 0.682 \\ \mathrm{C}_2 & 0.000 \\ \mathrm{C}_3 & 0.830 \\ \mathrm{C}_4 & 0.760 \\ \mathrm{C}_5 & 0.730 \\ \mathrm{C}_6 & 1.000 \\ \mathrm{C}_7 & 0.000 \\ \mathrm{C}_8 & 0.750 \\ \mathrm{C}_9 & 0.921 \\ \mathrm{C}_{10} & 0.844 \end{bmatrix} \quad MEFS_3=\begin{bmatrix} & \mathrm{M}_3 \\ \mathrm{C}_1 & 0.000 \\ \mathrm{C}_2 & 1.000 \\ \mathrm{C}_3 & 1.000 \\ \mathrm{C}_4 & 1.000 \\ \mathrm{C}_5 & 0.000 \\ \mathrm{C}_6 & 0.000 \\ \mathrm{C}_7 & 1.000 \\ \mathrm{C}_8 & 0.000 \\ \mathrm{C}_9 & 0.000 \\ \mathrm{C}_{10} & 0.000 \end{bmatrix}$$

C. Weight determination

Firstly，calculate the objective weight. According to SV_{ji} (j=1-10, i=1-3) which standardized from the feasible ME schemes and formula (10) - (12). Calculate the information entropy H_j and entropy weight, the results are shown in table 2 . Secondly, calculate the subjective weight. According to the experts' opinion ,taking pairwise priority judgment and grade between C_1~C_{10}, then identify the subjective weight in accordance with the cumulative score P_j and formula (13) ,the results as are shown in table 2.Finally, identify the compound weight W_j according to the formula (14) as is shown in table 2.

D. Calculating the comprehensive degree of nearness

Calculate the comprehensive degree of nearness of each feasible *ME* schemes to $MEIR^P$ and $MEIR^N$ by the formula (15) when the compound weights of all characteristic indexes are gained. The results are: Z_1=0.7309; Z_2=0.6545; Z_3=0.3132. For a combination of close-degree $Z_1>Z_2>Z_3$, the conclusion of the site selection is: the recommended scheme of industrial site is M_1.

IV. CONCLUSIONS

With ME analysis of extension engineering theory, the problem of industrial site comparison and selection is abstracted by the ME analysis model. After identifying the compound weight of every characteristic indexes by both qualitative and quantitative analyses, the optimal order of the feasible site selection schemes is gained through the measurement and comparison of comprehensive degree of nearness between every *ME* of feasible schemes and $MEIR^P$, $MEIR^N$.

Because of the disadvantage that the traditional method is not able to compare all ideal (the best or the worst) references which are out of the feasible set, the industrial site selection on ME model has a better objectivity. At the same time, with a case study of a coal preparation plant site selection, the operability and validity of reduction of which the model based on ME are further validated in the project site selection of industrial plant.

Tab.2 The Different Weights of Each Evaluating Index

indexes	objective weight		subjective weight		compound weight
	H_j	w_j	P_j	w'_j	W_j
C_1	0.9656	0.093	6	0.125	0.115
C_2	0.9657	0.093	4	0.083	0.077
C_3	0.9638	0.098	1	0.021	0.020
C_4	0.9648	0.096	1	0.021	0.020
C_5	0.9652	0.095	3	0.063	0.058
C_6	0.9621	0.103	9	0.188	0.190
C_7	0.9539	0.125	5	0.104	0.129
C_8	0.9650	0.095	3	0.063	0.059
C_9	0.9621	0.103	8	0.167	0.169
C_{10}	0.9636	0.099	8	0.167	0.163

ACKNOWLEDGEMENTS

Financial support was provided by scientific research projects of China Coal Xi'an Designing Co., Ltd. and engineering practice program of teachers of Xi'an University of Architecture and Technology.

REFERENCES

[1] Xiao-jian Li. Economic Geography (2nd edition). Higher Education Press, Beijing, 2006.

[2] Juan Wang and etc. Optimum choice of mine water decontamination plant site in Fuxin east mining area. Journal of Liaoning Technical University, Vol.25 No.5, pp.781-784, October 2006 (In Chinese).

[3] Enlong Ke. Optimizing site-selection of power plants with AHP. Engineering Journal of Wuhan University, Vol.40 Sul.1, pp. 81-83, October 2007 (In Chinese).

[4] Yongping Yang etc. The fuzzy optimization of the site selection for coal-fired power plants. Proceedings of the CSEE, Vol.26 No.24, pp.82-87, November 2006 (In Chinese).

[5] Corbett C, Decroix G. Shared saving contracts in supply chains. Management science, Vol 47 No.7, pp.881-893, July 2005.

[6] Wen Cai. Extension theory and its application. Chinese Science Bulletin, Vol 44, pp. 1538-1548, July 1999 (In Chinese).

[7] Jing Cui. Application of analysis of fuzzy matter-element based on entropy in evaluation on bidding documents. Chinese Journal of Systems Science, Vol 17 No.4, pp.61-64, October 2009 (In Chinese).

[8] Qizhou Hu, Wei Deng, Yuan Zhou. An extension method for the optimization of public traffic line network. Journal of Wuhan University of Technology(Transportation Science & Engineering), Vol 33 No.1, pp.25-28, February 2009 (In Chinese).

[9] Xiaoge Tian, Du Lin, Sunde Wu. Performance evaluation of Portland cement concrete pavement based on fuzzy complex matter element method. Journal of Traffic and Transportation Engineering, Vol 10 No.2, pp.26-29, April 2010 (In Chinese).

[10] Liping Zhou, Wenke Wang, Rongbo Ma. Application of method of entropy proportion to urban earthquake disaster risk index. Journal of Earthquake Engineering and Engineering Vibration, Vol 30 No.1, pp.93-97, February 2010 (In Chinese).