Brownfield Redevelopment Issues and Multi-Attribute Group Decision Making Model: The Way Forward

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Abstract

Modernization process has brought an economic development with immense production transformation and economic relocation of many organizations that left behind a lot of contaminated and discarded land. Nonetheless, it brought social changes wherein people' standard of living has improved sharply as well as the population growth; thus, the demand for different commodities has increased. For instance, lands 'demand is experiencing an exponential growth; hence, government sees in Brownfield Redevelopment (BR) an adequate mean to satisfy this increasing lands demand. However, Brownfield Redevelopment processes main characteristics are uncertainty and conflicts that stem from the involvement of many stakeholders having a complex relationship. Therefore, this paper one hand, applies Multi－Attribute Group Decision-Making model (MAGDM) to implement objective evaluation of uncertainty attribute on the interest subjects aiming to achieve united approval to the utmost extent; on the other hand, it uses the theory of the Relative Entropy to gather the different preference information of stakeholders. Finally, a decision-making mechanism is developed to conduct beneficial research into the theory of the Relative Entropy's application to China's BR's practice.

Keywords Brownfield Redevelopment, Interest Subjects, Multi-Attribute Group Decision Making Model, Relative Entropy Theory

I. Introduction

According to the Chinese National Bureau of Statistics (2010) the population has grown rapidly, and it was estimated at 0.137 billion. Furthermore, Chinese's standard of living has remarkably increased; therefore, the demand for lands has also sharply increased. As a result, the Chinese government and scientists alike are profoundly interested in the effective management of the redevelopment of the three hundred thousand brown fields [1], because it will have a huge impact on increasing lands supply.

The US Environmental Protection Agency (USEPA) defines Brown fields as abandoned, idle, or underutilized commercial or industrial properties where an active potential for redevelopment is restrained by known or suspected environmental contamination caused by past actions [2]. Thus, Brownfield can bring environmental and health risks. Nevertheless, restoration of Brownfield can range of economic, social, and environmental benefits [3].

Brownfield redevelopment processes main characteristics are uncertainty and conflicts that stem from the involvement of many stakeholders having a complex relationship. Therefore, to be sure that the process goes smoothly, we should effectively manage any conflict that arises between the different stakeholders. Hence, the purpose of this paper is to use the theory of the Relative Entropy to gather the unlike preference information about interest groups; thereafter, develop a decision-making mechanism of Brown field redevelopment.

This paper is organized as follows: Section 2 goes over the literature review about Brown field redevelopment and Multi－Attribute group decision–making (MAGDM model); Section 3 explains the principle of MAGDM model and evaluates the model's performance in developing decision-making mechanism for Brownfield Redevelopment; and Section 4 offers conclusions.

II. Literature Review

This section briefly goes over the literature review related to Brownfield Redevelopment and Multi-Attribute Group Decision Making.

2.1 Literature Reviews about Brownfield Redevelopment

Despite the dawn age of Brownfield redevelopment field, many researchers and agencies are showing their vest interest in this field. Hence, researchers clearly distinguished Brownfield Redevelopment from land development; for instance, Brownfield redevelopment involves numerous uncertain risks associated with market demand and land value (Chun Chen, 2013) [4]. G. Christopher Wedding (2007) sorts uncertainty risks into Environment；Finance；Societal Stability and Policy [5].

W.Hartley (2012) built a cost-benefit analysis framework to evaluate finance risks. An objective and effective evaluation index system is critical for Brownfield redevelopment (Zhu Yu-ming, 2011)[6]. In order to scientifically and reasonably evaluate the Brownfield redevelopment project, YU Ming-Jie (2011) [7] and GUO Peng (2009) [8] put forward some methods based on Principle Component Analysis and method set.

Jin Zhao (2011) identifies the connotation and characteristics of environmental risks based on the concepts of Brownfield [9]. Therefore, Mihcael (2007) pointed out environmental risks affect the government department's environmental policy [10]. Parrota. J. A (1991) has shown the use of a natural process to recover the ecological environment of Brownfield [11].

In summary, considerable research has addressed Brownfield Redevelopment issues, including basic theoretical analysis; uncertainty risks of BR and decision of BR. There have been relatively few qualitative tools to assist in BR decision, which based on conflicts among stakeholders.

2.2 Literature Reviews about Multi－Attribute Group Decision Making

Brownfield Redevelopment processes main characteristics are uncertainty and conflicts that stem from the involvement of many stakeholders having a complex relationship. Fortunately, many research initiatives have examined issues in Multi－Attribute group decision making. Zhibin Wu (2012) [12] presents a framework with theoretical results for the consistency, and consensus-based decision support model. Danielle (2012) [13] focused on group decision making based on the analysis of individual ranking and demonstrated that this method can be used to deal with many kinds of group decision making problems. Clearly, Technique for Oder Preference by Similarity to Ideal Solution (TOPSIS); Order Weighted Average (OWA); DEA and Evidence Reasoning Theory enrich the Multi－Attribute group decision making.

At present, entropy which is described as "the first law of science" has been used in almost all disciplines. Many scholars have applied the concept of entropy successfully in Multi－Attribute group decision analysis, and achieved many good results. Guo Kai-hong (2011) [14] proposed a linear method of Multi－Attribute group decision making with complete ignorance of weight information based on entropy and evidence distance. Aimed at the group decision-making problem, in which the information of weights and values of attribute are incomplete, Wan Shuping (2009) [15] proposed a method to determine weights based on the theory of relative entropy. In addition, Sandroni [16]; Xue [17] and Lei Li-cai [18]'s research about relative entropy is feasible and useful.

Under the umbrella of Multi－Attribute Group Decision Making (MAGDM), a model is designed for BR and applied to determine the decision weights based on relative entropy. A brief introduction of MAGDM is given next.

III. Interactive Multi-Attribute Group Decision Making Method for Brownfield Redevelopment Based on Relative Entropy

3.1 Issue & Symbols Description

Decision-making scheme formulates cannot be "overnight" or "once and for all" must be the general problem of the Brownfield Redevelopment decision-making, the decision-making mainly comprise repeatedly discussions, consultation, comparison and adjustment to obtain “Compromise Solution” or “Satisfactory Solution” which decision-making group can accept, making the feasible region of the Brownfield Redevelopment decision-making gradually converge to the optimal solution along with the information’s completing.

Let $A = \{a_1, a_2, \ldots \ldots a_n\}$denote solution sets of Multi-Attribute Group Decision-Making problems under an uncertaincircumstance, with a set of properties$F = \{f_1, f_2, \ldots \ldots f_n\}$ and decision-makinggroup$E = \{e_1, e_2, \ldots \ldots e_k\}$ while K people involved in decision-making.

We use$\omega^k = \{\omega_j^k \,|\, \sum_{j=1}^{n} \omega_j^k = 1, \omega_j^k \geq 0, j = 1,2, \ldots \ldots n\}$ to denote the weights vector of attribute the judgment which decision-making expert$e_k$made. Settingλ_k as the weight of decision maker k, to any $k \in \{1,2, \ldots \ldots, K\}$,there is $\lambda_k \geq 0, \sum_{k=1}^{K} \lambda_k = 1$.$\tilde{z}_{ij}^k$is the value of judgment made by decision makere_k about programa_i with the attribute f_j,we set $\tilde{z}_{ij}^k$ as a Triangular Fuzzy Number, that is $\tilde{z}_{ij}^k = [z_{ijl}^k, z_{ijm}^k, z_{ijn}^k]$,so we can get a fuzzy decision matrix$\tilde{z}_{ij}^k = (\tilde{z}_{ij}^k)_{m\times n}$as depicted in the following formula:

$$\tilde{z}^k = \begin{array}{c|cccc} & f_1 & f_2 & \cdots & f_n \\ a_1 & \tilde{z}_{11}^k & \tilde{z}_{12}^k & \cdots & \tilde{z}_{1n}^k \\ a_2 & \tilde{z}_{21}^k & \tilde{z}_{22}^k & \cdots & \tilde{z}_{2n}^k \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_m & \tilde{z}_{m1}^k & \tilde{z}_{m2}^k & \cdots & \tilde{z}_{mn}^k \end{array}$$

In order to simplify the tedious calculation process of Fuzzy Numbers, Bortolan. G (1985) indicated that we can use $z = \frac{\int_{z_1}^{z_3} x \mu_{\tilde{z}(x)} dx}{\int_{z_1}^{z_3} \mu_{\tilde{z}(x)} dx} = \frac{\int_{z_1}^{z_2} \left(x \cdot \frac{x - z_1}{z_2 - z_1}\right) dx - \int_{z_2}^{z_3} \left(x \cdot \frac{z_3 - x}{z_3 - z_2}\right) dx}{\int_{z_1}^{z_2} \left(\frac{x - z_1}{z_2 - z_1}\right) dx - \int_{z_2}^{z_3} \left(\frac{z_3 - x}{z_3 - z_2}\right) dx} = \frac{z_1 + z_2 + z_3}{3}$to get the fuzzified Value of Fuzzy Number $Z = (z_1, z_2, z_3)$.

In addition, there are two types of properties in multi-attribute decision making problems: benefit attribute and cost attribute. To facilitate comparative analysis between attributes, we standardized the value of utility in the decision matrix, i.e. to benefit attribute, let $u_{ij}^k = z_{ij}^k / \sum_{i=1}^{m} z_{ij}^k, i = 1,2, \ldots \ldots, m, j = 1,2, \ldots \ldots, n, k = 1,2, \ldots \ldots, K$ and to cost attribute let $u_{ij}^k = \frac{1/z_{ij}^k}{\sum_{i=1}^{m} 1/z_{ij}^k}, i = 1,2, \ldots \ldots, m, j = 1,2, \ldots \ldots, n, k = 1,2, \ldots \ldots, K$, so we can get standard expecteddecision matrix:$D^k = (u_{ij}^k)_{m\times n}$, for$\forall\, i, j, k$, there is $0 \leq u_{ij}^k \leq 1$.

Before give the interactive solving algorithm of negotiation model of Brownfield redevelopment multi-attribute group decision-making, based on Yan H (2002)[19] ,we first presents two definitions below:

Definition 1: If$\exists \beta \in R^1$, and the attribute weights vector $\omega^k = (\omega_1^k, \omega_2^k, \ldots \ldots \omega_n^k)^T \in \{\omega^k \,|\, e^T \omega^k = 1, \omega^k \geq 0\}$meets the condition $\sum_{j=1}^{n}\omega_j^k u_{rj}^k \geq \sum_{j=1}^{n}\omega_j^k u_{sj}^k + \beta$, then decision maker e^k will think scheme a_r is superior to the scheme a_s, recorded as $a_r > a_s$.

Among them, $1 \leq r, s \leq m, r \neq s, e = (1,1,\cdots 1)^T \in R^n$, while beta reflects the extent scheme a_r is better than that of a_s, and also ω^k reflects the weights vector of attribute which decision-making expert e_k thought.

Definition 2: Let $\overline{\omega}^k = (\overline{\omega}_1^k, \overline{\omega}_2^k, \cdots, \overline{\omega}_n^k)^n \in \omega^k, e^T\overline{\omega}^k = 1, \overline{\omega}^k \geq 1$, and there is $\overline{\beta} \geq 0$ make the inequality $u_r^s\overline{\omega}^k \geq \overline{\beta}, (r,s) \in U_{k=1}^{k} I^k$ be established. Hence, $\overline{\omega}^k$ was named as Compromise Weight Vector of attributes of group decision-making, while $\overline{\beta}$ was called as Compromise Index.

To definition 2 there are several supplementary explanations: It is assumed that decision maker e_k compared all schemes respectively, in such a way that the order of preference is $a_{k(1)} > a_{k'(1)}, a_{k(2)} > a_{k'(2)}, \cdots, a_{k(T_k)} > a_{k'(T_k)}$, where T_k is the number of schemes' pairs which compared with each other, e.g. The preference of e^1 is $a_3 > a_1, a_3 > a_5$,so, $I_1 = \{(3,1),(3,5)\}$, the preference of e^2 is $a_2 > a_1, a_2 > a_4, a_5 > a_3$,so, $I_2 = \{(2,1),(2,4),(5,3)\}$. While $u_r^s = (u_{r1}^k - u_{s1}^k, u_{r2}^k - u_{s2}^k, \cdots, u_{rm}^k - u_{sm}^k)$, that, $(r,s) \in U_{k=1}^{K} I_k$.

3.2 Solve the weights of decision makers of Brownfield Redevelopment

Similar to Xue (2009) [17], solving process of attributes compromise weight of Brownfield redevelopment multi-attribute group decision-making is as follows:

First, get I_k and u_s^r when each decision makers give their preference orderof schemes for two paired comparison.

Next, use the utility function of decision makers for each scheme as the objective function of Brownfield Redevelopment decision problems, and assume that the marginal utility function of each attribute is independent. According to expected utility theory, we can get the multi- attribute utility function of scheme a_i by using linear weighted method, i.e. $V(a_i) = \sum_{k=1}^{K}\lambda_k \sum_{j=1}^{n}\omega_j^k u_{ij}^k$. It is unable to use the above utility function to build the total order relation on solutions because the weight vector of attributes $\omega^k = (\omega_1^k, \omega_2^k, \ldots\ldots \omega_n^k)^T$ and the weight of decision-making expert λ_k are unknown. Now use Linear Programming LP1 to find out the solution of ω^k, define LP1 as follow:

$\max \beta$

s.t.$\mathbf{u}_s^r \omega^k \geq \beta$

$(r, s) \in U_{k=1}^{k} I^k$ LP1

$\mathbf{e}^T \omega^k = \mathbf{1}, \omega^k \geq 0$

Define $\hat{\beta}$ and $\hat{\omega}^k$ as the optimal solution of LP1, if $\hat{\beta} \geq \mathbf{0}$, all the decision makers will agree tis programa$\mathbf{a}^r > \mathbf{a}_s$, $(\mathbf{r}, \mathbf{s}) \in \mathbf{U}_{k=1}^{K} \mathbf{I}_k$ without any objection, $\hat{\omega}^k$ will be the compromise weight of attribute satisfiedall decision makers; Else, if $\hat{\beta} < \mathbf{0}$, namely that compromise weight does not exist, decision makers could not reach a consensus opinion, some decision makers should adjust their preference to achieve consensus due to the third process follows.

Assume $\hat{\mathbf{I}}_k = \{(\mathbf{r}, \mathbf{s}) | \mathbf{u}_s^r \hat{\omega}^k = \hat{\beta}, (\mathbf{r}, \mathbf{s}) \in \mathbf{I}_k\}$ for each k=1, 2,……, K, for any $(\dot{\mathbf{r}}, \dot{\mathbf{s}}) \in \mathbf{U}_{k=1}^{k} \hat{\mathbf{I}}^k$, build a Linear Programming LP2 as follow:

Max$\mathbf{u}_{\dot{s}}^{\dot{r}} \omega^k$

s.t.$\mathbf{u}_s^r \omega^k \geq \hat{\beta}$

$(\mathbf{r}, \mathbf{s}) \in \mathbf{U}_{k=1}^{K} \mathbf{I}^k$ LP2

$\mathbf{e}^T \omega^k = \mathbf{1}, \omega^k \geq 0$

Define $\omega_{\dot{s}}^{\dot{r}}$ for any $(\dot{\mathbf{r}}, \dot{\mathbf{s}}) \in \mathbf{U}_{k=1}^{k} \hat{\mathbf{I}}^k$ as the optimal solution of LP1, and$\hat{\hat{\mathbf{I}}}_k = \{(\mathbf{r}', \mathbf{s}') | \mathbf{u}_{s'}^{r'} \omega_{s'}^{r'}(\mathbf{k}) = \hat{\beta}, (\mathbf{r}', \mathbf{s}') \in \hat{\mathbf{I}}_k\}$ for each k=1, 2,……,K, then continue to the next process.

According to the above solving process, building the following linear programming model (LP3):

$\max \beta$

s.t.$\mathbf{u}_s^r \omega^k \geq \beta$

$(r, s) \in U_{k=1}^{k} I^k \backslash U_{k=1}^{k} \hat{I}^k$

$\mathbf{e}^T \omega^k = \mathbf{1}, \omega^k \geq 0$

Define $\bar{\beta}$ and $\bar{\omega}^k$ as the optimal solution of LP1, if $\bar{\beta} \geq 0$, $\bar{\omega}^k$ will be the compromise weight of attribute satisfied all decision makers; Else, if $\bar{\beta} < 0$, turn back to the third process and use $\bar{\beta}$ to instead of $\hat{\beta}$.

Finally By the above process, the compromise weight of attribute has been worked out, and then the utility value $V_i^k = \sum_{j=1}^n \omega_j^k u_{ij}^k$ on a_i of decision maker e_k can be obtained by putting the compromise weight of attribute into the utility function of the formula (1). But as a result of the weight vector of decision-making expert is unknown, we still can't set the total order relation of the schemes. Each decision-making expert usually have different knowledge background, cognitive level and practice experience, therefore, to determine the weighing values of experts should fully reflect the decision-making level. Here is a kind of empowerment method which is based on fuzzy set theory, can objectively reflect the expert's decision-making level. This metric calculation process can actually be a special form as reference [35], concrete calculation process is as follows: converting the utility value V_i^k into triangular fuzzy number: $\tilde{V}^k = (V_{k1}, V_{k2}, V_{k3}) = \{[\min(V_1^k, V_2^k, \cdots V_m^k)], [\sum_{i=1}^m V_i^k/m], [\max(V_1^k, V_2^k, \cdots V_m^k)]\}$,define V_{k1} as the utility value of least favorite scheme for decision maker e_k, on behalf of the pessimistic estimate; And V_{k3} as the utility of decision maker e_k's preference scheme, on behalf of the optimistic estimate; V_{k2} is saidto be the utility value of the scheme that decision maker e_k most likely to adopt. Yu. L (2009) [19] have proved that the optimal weights value of decision-making expert e_k is $\lambda^* = (B^{-1}e)/(e^T B^{-1} e)$, where the matrix B is:

$$B = (b_{ij})_{K\times K} =$$

$$\begin{bmatrix} (K-1)(\sum_{l=1}^{3} v_{1l}^2) & -\sum_{l=1}^{3} v_{1l}v_{2l} & \cdots & -\sum_{l=1}^{3} v_{1l}v_{Kl} \\ -\sum_{l=1}^{3} v_{2l}v_{1l} & (K-1)(\sum_{l=1}^{3} v_{2l}^2) & \cdots & -\sum_{l=1}^{3} v_{2l}v_{Kl} \\ \vdots & \vdots & \ddots & \vdots \\ -\sum_{l=1}^{3} v_{Kl}v_{1l} & -\sum_{l=1}^{3} v_{Kl}v_{2l} & \cdots & (K-1)(\sum_{l=1}^{3} v_{Kl}^2) \end{bmatrix}$$

Thus we can get the weight of every decision-making expert objectively, to avoid many disadvantages by subjectively valuation.

3.3 Gather the Different Preference of Stakeholders Based on Relative Entropy

After the weight of attribute and the compromise weight of decision makers of multi-attribute group decision-making problem of Brownfield Redevelopment being known, we can bring them into the utility function V(a_i)=∑_(k=1)^K▒λ_k ∑_(j=1)^n▒ω_j^k u_ij^k to calculate the utility value of each scheme, but how to collect preference information of the decision-making group to maximize the consistency of decision-making group preference and coordinate the interests or conflicts between different decision-makers to build total order relations on solution set? Therefore, relative entropy assembly model is used to gather the preferences of the decision-making group. First of all, according to the Shannon's information entropy theory, Relative entropy concept and nature of the discrete form is given as follows:

Definition 3: Forx_i,y_i≥0,i=1,2,⋯,n, let Ω={0,1,2,⋯,n},x_i,y_i are two probability measures of Ω, and ∑_(i=1)^n▒x_i ≥∑_(i=1)^n▒y_i ,let X=(x_1,x_2,⋯,x_n),Y=(y_1,y_2,⋯,y_n),define h(X,Y)=∑▒x_i log x_i/y_i ≥0 to be the relative entropy of X to Y.

Obviously, the relative entropy of X, Y satisfies the following properties:

If and only if xi=yi

According to the above properties, when distribution for X and Y is discrete distribution, relative entropy can be used to measure the degree of coincidence, and the relative entropy value will be minimum if the distribution of X and Y to be the same. Therefore, we can use the relative entropy to measure the degree of coincidence of the decision-makers' preferences of the Brownfield Redevelopment multi-attribute group decision-making I.e Relative entropy value of a zero means group reached consensus opinions, there is no disagreement; Relative entropy value of 1 means that the decision-making group didn't reach consensus, and every individual decision maker insisted their own opinion, there was large difference in opinions.

For any k, if we use the utility value of decision-makere_kin the decision-making scheme set to be a probability measure of each program preferences' utility. The discrete probability measure of all the decision-making scheme of each decision maker forms a probability distribution of the decision-making plan set. Without losing generality; we assume that the decision-maker judge the attribute values of each scheme under independent condition, that is to say, the probability distribution of the decision-making scheme is independent from each other.

Define, to be a preference vector of a decision making group. According to the nature of the relative entropy, in order to coordinate preference among stakeholders we must make group utility value is minimum relative to each individual So

S.T.

Vki is the utility value of ek about the project ai; the answer of this optimization problem is depending on the value of can get the "Satisfaction" project.

IV. Conclusion

As the legacy of a century of industrialization, government and academic circles have attached great importance to the Brownfield Redevelopment. Conclusions drawn upon the study of Brownfield Redevelopment are follows：

（1）At present, land pollution is serious China; most of the contaminated land is idle or underused. The existence of Brownfield is not only a waste of land, which can hinder urban construction and economic development, but pose risks to the environment and people's health. The key to Brownfield Redevelopment is how to coordinate conflict among stakeholders, and government need pay attention to this issue and build a decision-making mechanism in order to promote Brownfield Redevelopment.

(2) The process of Brownfield Redevelopment is complicated because of uncertain factors and the involvement of various stakeholders. So we must determine the decision weights during the decision-making process by carefully considering the importance of the stakeholders and influence factors. This article uses the interactive Multi-Attribute Group Decision-Making method to determine and optimize the weights of decision-making and stakeholders. Searching for satisfactory solution between different stakeholders is more objective and reasonable and can avoid the shortcomings of subjective weight-determining.

(3) There is conflict of interest among the stakeholders in Brownfield Redevelopment. The theory of Relative Entropy can aggregate group's preference effectively and coordinate conflicts among stakeholders. The mechanism built by the theory of Relative Entropy can enhance the fairness of decision-making, and could be helpful in setting the most satisfactory solution.

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