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Establishment of the Index System for Evaluation of Brownfield Redevelopment Projects in China

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***Abstract*—An index system for the evaluation of the Brownfield Redevelopment Projects in China is proposed. This index system involves the four dimensions consisting of Social and Economic, Financial and Accounting, Environmental and Health, and Prospective Value. Each dimension includes some criteria. With the help of software SPSS, the reliability and satisfaction of the proposed index system are proven by calculating the value of Cronbach's alpha and doing a one sample t-test. Additionally, the driving forces of each dimension are identified by using multiple regression analysis.**

***Keywords*—evaluation index system, establishment, brownfield redevelopment project**

I. INTRODUCTION

After decades of efforts, the concept of sustainable development has been accepted and adopted as policy by most governments, for-profit organizations, non-profit organizations, and individuals [1][2]. The World Business Council on Sustainable Development (WBCSD) defined sustainable development as "forms of progress that meet the needs of the present without compromising the ability of future generations to meet their needs [1]". In 2002, the World Summit on Sustainable Development listed seven key points of sustainable development: (1) eradicating poverty, (2) changing unsustainable production and consumption patterns, (3) protecting and managing the natural resources base of economic and social development, (4) sustainable development in a globalizing world, (5) health and sustainable development, (6) sustainable development of small-island developing states, and (7) sustainable development for Africa [3].

Brownfield redevelopment is a concrete application of the concept of sustainable development [4]. Many countries have given their own definitions of brownfields, according to their own characteristics [5]. Among these definitions, the most commonly cited is the one from the US Environmental Protection Agency (USEPA), which defines brownfields 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 [6]". Undoubtedly, restoration and redevelopment of brownfields can provide a range of economic, social, and environmental benefits, including restoration of environmental quality and improvement of quality of life for citizens, elimination of health threats, provision of land for housing or commercial purposes, creation of employment opportunities, expansion of the tax base for all levels of government, and reduction in the pressure on urban centers to expand into greenfields [7].

Thus, brownfields have recently become the focus of attention for governments, communities, environmental advocates, scientists, and researchers around the world. Considerable research has addressed brownfield redevelopment issues including development of remediation technologies, environmental assessment, risk assessment and management, financial arrangements, and community and public involvement [8]. Many methodologies from the fields of social science and management science have been applied to handle challenging environmental management problems. Among these methodologies, the project evaluation method can be of great value to decision makers. As the first and main step of project evaluation, the establishment of the evaluation index system plays a very important role and also paves the way for further project evaluation tasks.

The rest of the paper is organized as follows: the Index System for Evaluation of Brownfield Redevelopment Project, which is suitable for the current situation of China is proposed in Section II; reliability analysis and one sample t-test of the index system is given in Section III; the main driving-forces of each dimension are identified in Section IV; and some conclusions and future work are presented in Section V.

II. INDEX SYSTEM FOR EVALUATION OF BROWNFIELD REDEVELOPMENT PROJECT

The establishment of an index system for the evaluation of a brownfield redevelopment project is the main task of the project evaluation-based research framework [9]. Some researchers have proposed several index systems from different perspectives. For example, P. Syms [10] has identified six

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groups of decision-making factors which are relevant to the redevelopment of brownfield land; C. A. De Sousa [11] proposed his index system from three aspects which are environmental benefits, social benefits and economic benefits; G.C. Wedding et al [4] proposed an index system to assess the success of redevelopment in meeting sustainability goals, including multi-stakeholder perspectives, green building elements, and site-level details.

By taking the characteristics of brownfields in China [9] and the requirements of sustainable development [3] into account, we propose our index system (see TABLE I), which includes four dimensions, which are social and economic, financial and accounting, environmental and health, and prospective value (see second column of TABLE I). Each dimension has some detailed criteria (see third column of TABLE I).

III. Reliability Analysis and One Sample T-Test of the Proposed Index System

A. Reliability Analysis of Proposed Index System

We use reliability coefficient to test the reliability of the proposed index system. To accomplish this, we designed a questionnaire, which included all of the criteria and was based on the Likert Scale. To facilitate the upcoming criteria weighting work, which will use the AHP [15] method, we used the nine-level item instead of the typical five-level Likert item. The format of our nine-level item is: 1-Strongly Disagree; 2-Somewhere between Strongly Disagree and Disagree; 3-Disagree; 4- Somewhere between Disagree and Neither Agree or Disagree; 5- Neither Agree or Disagree; 6- Somewhere between Neither Agree or Disagree and Agree; 7-Agree; 8-Somewhere between Agree and Strongly Agree; 9-Strongly Agree. To collect data, we sent out 500 questionnaires to major stakeholders of brownfield redevelopment, which included relevant government divisions, brownfield owners, brownfield developers, the financial sector, public representatives, and others. The number of returned questionnaires is 340. Among them, 335 questionnaires are valid. The rate of validity is 98.53%.

TABLE I. Index System for Evaluation of Brownfield Redevelopment Project and Its Item Descriptive Statistics

	Dimensions	Criteria	Mean	Std. Deviation	N
Index System for Evaluation of Brownfield Redevelopment Project	Social and Economic	Improvement of image of local community and government	6.98	1.699	328
		Matchup with city planning	7.10	1.506	328
		Improvement of living quality of local residents	6.94	1.662	328
		Improvement of local security status	5.84	1.902	328
		Increase local employment rates	6.04	1.860	328
		Increase land value of neighborhood	6.95	1.690	328
		Increase local tax base	6.19	1.849	328
		Easing the pressure on green land development	6.56	1.798	328
		Protecting and recycling the land / soil resource	7.06	1.787	328
		Improvement of remediation technologies	6.83	1.789	328
	Financial and Accounting	Net present value (NPV)	6.84	1.495	334
		Return on investment (ROI)	7.03	1.606	334
		Payback period (PP)	6.98	1.594	334
		Total cost of Brownfield remediation and construction	6.90	1.562	334
		Ratio of Brownfield remediation cost to total cost	6.82	1.627	334
	Environmental and Health	Lowering the health risks of local residents	7.06	1.572	333
		Improvement of soil quality	7.01	1.685	333
		Improvement of the quality of underground water	7.14	1.700	333
		Improvement of air quality	6.88	1.794	333
		Increase of green cover percentage	6.96	1.738	333
	Prospective Value	Size of brownfield	7.02	1.400	332
		Location of brownfield	7.04	1.533	332
		Transportation convenience of brownfield area	6.77	1.587	332
		Status of infrastructure facilities of brownfield area	6.75	1.533	332
		Influence from other nearby contamination hazards	7.01	1.545	332
		Technological difficulties and time requirement of brownfield remediation	6.97	1.395	332
		Influence from policy and legislation	7.26	1.588	332

The most commonly used reliability coefficients is Cronbach's alpha [13], which is based on the average correlation of items within a test if the items are standardized. The equation of Cronbach's alpha is:

$$\alpha = \frac{k}{k-1}\left(1-\frac{\sum_{i=1}^{k}\operatorname{var}(i)}{\operatorname{var}}\right) \quad (1)$$

TABLE II. CRONBACH'S ALPHA OF ITEMS FROM DIMENSION OF SOCIAL AND ECONOMIC

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Improvement of image of local community and government	59.50	113.462	0.545	0.350	0.847
Matchup with city planning	59.38	115.453	0.568	0.407	0.846
Improvement of living quality of local residents	59.54	113.405	0.563	0.391	0.846
Improvement of local security status	60.64	111.924	0.511	0.372	0.851
Increase local employment rates	60.44	109.806	0.586	0.455	0.844
Increase land value of neighborhood	59.53	114.268	0.525	0.362	0.849
Increase local taxation base	60.29	109.387	0.602	0.465	0.842
Easing the pressure on green land development	59.92	109.529	0.620	0.488	0.841
Protecting and recycling the land / soil resource	59.42	112.060	0.551	0.571	0.847
Improvement of remediation technologies	59.65	110.338	0.600	0.554	0.843
Reliability Coefficients N of Items=10 Cronbach's Alpha=0.859					

TABLE III. CRONBACH'S ALPHA OF ITEMS FROM DIMENSION OF FINANCIAL AND ACCOUNTING

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Net present value (NPV)	27.73	27.789	0.602	0.397	0.844
Return on investment (ROI)	27.53	25.343	0.717	0.531	0.814
Payback period (PP)	27.59	25.726	0.696	0.493	0.820
Total cost of Brownfield remediation and construction	27.66	26.140	0.684	0.501	0.823
Ratio of Brownfield remediation cost to total cost	27.75	25.985	0.656	0.473	0.831
Reliability Coefficients N of Items=5 Cronbach's Alpha=0.856					

TABLE IV. CRONBACH'S ALPHA OF ITEMS FROM DIMENSION OF ENVIRONMENTAL AND HEALTH

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Lowering the health risk of local residents	27.73	27.789	0.602	0.397	0.844
Improvement of soil quality	27.53	25.343	0.717	0.531	0.814
Improvement of the quality of underground water	27.59	25.726	0.696	0.493	0.820
Improvement of air quality	27.66	26.140	0.684	0.501	0.823
Increase of green cover percentage	27.75	25.985	0.656	0.473	0.831
Reliability Coefficients N of Items=5 Cronbach's Alpha=0.898					

TABLE V. CRONBACH'S ALPHA OF ITEMS FROM DIMENSION OF PROSPECTIVE VALUE

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Size of brownfield	41.80	46.702	0.574	0.379	0.838
Location of brownfield	41.78	43.500	0.683	0.509	0.823
Transportation convenience of brownfield area	42.05	42.641	0.699	0.558	0.820
Status of infrastructure facilities of brownfield area	42.08	43.707	0.670	0.497	0.824
Influence from other nearby contamination hazards	41.82	45.158	0.583	0.382	0.837
Technological difficulties and time requirement of brownfield remediation	41.86	46.106	0.612	0.412	0.833
Influence from policy and legislation	41.56	46.464	0.493	0.301	0.851
Reliability Coefficients N of Items=7 Cronbach's Alpha=0.853					

Because Cronbach's alpha can be interpreted as correlation coefficient, it ranges in value from 0 to 1. Normally, the value falls within the range of 0.60 to 0.65, and the reliability of the questionnaire will be regarded as questionable. The value within 0.65-0.70 implied minimum acceptable. The value within 0.70-0.80 implied fairly good. The value within 0.80-0.90 or above implied very good [14].

By using software SPSS 16.0, we did descriptive statistics analysis (see TABLE I) and calculated the value of Cronbach's alpha for all four dimensions. The results are listed in TABLE II –TABLE V.

From the results, we can learn that (1) the value of Cronbach's alpha for every dimension is higher than 0.850, (2) deleting no items (criteria) can make the value of Cronbach's alpha higher than the original one. Therefore, from the perspective of reliability coefficient, we proved the reliability of our proposed index system.

B. *One Sample T-Test of the Proposed Index System*

The one-sample t-test is used when you have data from a single survey of participants and you wish to know if the mean of the population from which the sample is drawn is the same as the hypothesized mean [13]. Here, we let the hypothesized mean be 5. The results (see TABLE VI) indicate that there is a significant difference between the mean of the population and the hypothesized mean, because all two-tail significances (p value) of all dimensions and criteria are much less than 0.05. In addition, all means of dimensions and criteria are more than 5,

TABLE VI. ONE-SAMPLE STATISTICS AND TEST

	Test Value = 5									
	N	Mean	Std. Deviation	Std. Error Mean	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference: Lower	Upper
Social and Economic	335	7.52	1.532	.084	30.142	334	0.000	2.522	2.36	2.69
Financial and Accounting	335	7.06	1.542	.084	24.491	334	0.000	2.063	1.90	2.23
Environmental and Health	335	7.41	1.663	.091	26.584	334	0.000	2.415	2.24	2.59
Prospective Value	333	6.85	1.724	.094	19.583	332	0.000	1.850	1.66	2.04
Improvement of image of local community and government	335	7.52	1.532	0.084	30.142	334	0.000	2.522	2.36	2.69
Matchup with city planning	335	7.06	1.542	0.084	24.491	334	0.000	2.063	1.90	2.23
Improvement of living quality of local residents	335	7.41	1.663	0.091	26.584	334	0.000	2.415	2.24	2.59
Improvement of local security status	333	6.85	1.724	0.094	19.583	332	0.000	1.850	1.66	2.04
Increase local employment rates	335	6.97	1.696	0.093	21.293	334	0.000	1.973	1.79	2.16
Increase land value of neighborhood	335	7.09	1.511	0.083	25.354	334	0.000	2.093	1.93	2.25
Increase local taxation base	334	6.96	1.663	0.091	21.557	333	0.000	1.961	1.78	2.14
Easing the pressure on green land development	335	5.83	1.895	0.104	8.016	334	0.000	.830	.63	1.03
Protecting and recycling the land / soil resource	335	6.04	1.851	0.101	10.331	334	0.000	1.045	.85	1.24
Improvement of remediation technologies	333	6.96	1.685	0.092	21.238	332	0.000	1.961	1.78	2.14
Net present value (NPV)	335	6.17	1.854	0.101	11.520	334	0.000	1.167	.97	1.37
Return on investment (ROI)	335	6.58	1.796	0.098	16.059	334	0.000	1.576	1.38	1.77
Payback period (PP)	333	7.08	1.787	0.098	21.288	332	0.000	2.084	1.89	2.28
Total cost of Brownfield remediation and construction	332	6.82	1.789	0.098	18.531	331	0.000	1.819	1.63	2.01
Ratio of Brownfield remediation cost to total cost	335	6.83	1.496	0.082	22.390	334	0.000	1.830	1.67	1.99
Lowering the health risk of local residents	335	7.03	1.607	0.088	23.082	334	0.000	2.027	1.85	2.20
Improvement of soil quality	335	6.96	1.606	0.088	22.384	334	0.000	1.964	1.79	2.14
Improvement of the quality of underground water	335	6.90	1.561	0.085	22.297	334	0.000	1.901	1.73	2.07
Improvement of air quality	334	6.82	1.627	0.089	20.410	333	0.000	1.817	1.64	1.99
Increase of green cover percentage	335	7.06	1.570	0.086	24.041	334	0.000	2.063	1.89	2.23
Size of brownfield	335	7.01	1.687	0.092	21.791	334	0.000	2.009	1.83	2.19
Location of brownfield	335	7.13	1.697	0.093	22.960	334	0.000	2.128	1.95	2.31
Transportation convenience of brownfield area	334	6.88	1.792	0.098	19.177	333	0.000	1.880	1.69	2.07
Status of infrastructure facilities of brownfield area	334	6.96	1.739	0.095	20.636	333	0.000	1.964	1.78	2.15
Influence from other nearby contamination hazards	334	7.01	1.400	0.077	26.299	333	0.000	2.015	1.86	2.17
Technological difficulties and time requirement of brownfield remediation	334	7.04	1.529	0.084	24.371	333	0.000	2.039	1.87	2.20
Influence from policy and legislation	334	6.77	1.583	0.087	20.460	333	0.000	1.772	1.60	1.94
Improvement of image of local community and government	334	6.75	1.529	0.084	20.894	333	0.000	1.749	1.58	1.91
Matchup with city planning	334	7.01	1.542	0.084	23.772	333	0.000	2.006	1.84	2.17
Improvement of living quality of local residents	334	6.97	1.392	0.076	25.856	333	0.000	1.970	1.82	2.12
Improvement of local security status	332	7.26	1.588	0.087	25.963	331	0.000	2.262	2.09	2.43

which indicate that the stakeholders think all dimensions and criteria we selected are important to the evaluation of brownfield redevelopment projects.

an equation that represents the best prediction of a dependent variable which is correlated with the independent variable [13].

TABLE VII. DRIVING FORCES ANALYSIS FOR DIMENSION OF SOCIETAL AND ECONOMIC*

Model		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
		B	Std. Error	Beta	T	Sig.	Lower Bound	Upper Bound
1	(Constant)	2.076	0.416		4.995	0.000	1.258	2.894
	Improvement of image of local community and government	0.179	0.050	0.198	3.601	0.000	0.081	0.277
	Matchup with city planning	0.288	0.059	0.282	4.900	0.000	0.172	0.404
	Improvement of living quality of local residents	0.116	0.053	0.125	2.206	0.028	0.013	0.219
	Improvement of local security status	-0.044	0.045	-0.055	-0.981	0.327	-0.133	0.045
	Increase local employment rate	0.049	0.050	0.059	0.977	0.329	-0.049	0.146
	Increase land value of neighborhood	0.093	0.050	0.103	1.852	0.065	-0.006	0.193
	Increase local taxation base	-0.060	0.050	-0.073	-1.197	0.232	-0.159	0.039
	Easing the pressure on green land development	0.004	0.053	0.004	0.069	0.945	-0.101	0.108
	Protecting and recycling the land / soil resource	0.043	0.058	0.050	0.737	0.461	-0.072	0.157
	Improvement of remediation technologies	0.104	0.057	0.121	1.827	0.069	-0.008	0.216

* Dependent Variable: Societal and Economic

TABLE VIII. DRIVING FORCES ANALYSIS FOR DIMENSION OF FINANCIAL AND ACCOUNTING*

Model		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
		B	Std. Error	Beta	T	Sig.	Lower Bound	Upper Bound
1	(Constant)	2.369	0.389		6.088	0.000	1.603	3.134
	Net present value (NPV)	0.148	0.059	0.146	2.497	0.013	0.031	0.265
	Return on investment (ROI)	0.223	0.063	0.236	3.564	0.000	0.100	0.347
	Payback period (PP)	0.093	0.061	0.097	1.525	0.128	-0.027	0.212
	Total cost of Brownfield remediation and construction	0.160	0.062	0.164	2.559	0.011	0.037	0.283
	Ratio of Brownfield remediation cost to total cost	0.055	0.058	0.059	0.941	0.347	-0.060	0.170

*Dependent Variable: Financial and Accounting

TABLE IX. DRIVING FORCES ANALYSIS FOR DIMENSION OF ENVIRONMENT AND HEALTH*

Model		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
		B	Std. Error	Beta	T	Sig.	Lower Bound	Upper Bound
1	(Constant)	3.589	0.401		8.962	0.000	2.801	4.377
	Lowering the health risk of local resident	0.033	0.071	0.032	0.468	0.640	-0.107	0.174
	Improvement of soil quality	-0.065	0.076	-0.066	-0.854	0.394	-0.213	0.084
	Improvement of the quality of underground water	0.154	0.075	0.157	2.040	0.042	0.005	0.302
	Improvement of air quality	0.228	0.070	0.246	3.232	0.001	0.089	0.366
	Increase of green cover percentage	0.200	0.070	0.209	2.852	0.005	0.062	0.338

*Dependent Variable: Environment and Health

IV. DRIVING FORCE ANALYSIS FOR EACH DIMENSION OF THE INDEX SYSTEM

Driving force analysis for each dimension is to identify which criteria will play a more important role in evaluation so as to give the guidance to follow-up criteria weighting task. We performed driving forces analysis by using multiple regressions, which is an extension of bivariate correlation, and the result is

While doing the multiple regression analysis, we used all four dimensions as dependent variables and the criteria we chose for them were independent variables. From the value of regression coefficient (see TABLE VII -TABLE X), we can tell the comparative importance of each criterion. For instance, for the dimension of prospective value, the criteria are size of brownfield (B = 0.245), influence from other nearby contamination hazards (B=0.191) and location of brownfield (B=0.136), are more important considerations for the stakeholders who are making decisions. Similarly, we can identify the driving forces for the other three dimensions.

TABLE X. DRIVING FORCES ANALYSIS FOR DIMENSION OF PROSPECTIVE VALUE*

Model		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
		B	Std. Error	Beta	T	Sig.	Lower Bound	Upper Bound
1	(Constant)	2.030	0.566		3.586	0.000	0.916	3.144
	Size of brownfield	0.245	0.077	0.199	3.184	0.002	0.094	0.397
	Location of brownfield	0.136	0.079	0.121	1.722	0.086	-0.019	0.292
	Transportation convenience of brownfield area	0.047	0.081	0.043	0.581	0.562	-0.112	0.207
	Status of infrastructure facilities of brownfield area	0.097	0.078	0.086	1.234	0.218	-0.057	0.251
	Influence from other nearby contamination hazards	0.191	0.070	0.170	2.721	0.007	0.053	0.329
	Technological difficulties and time requirement of brownfield remediation	0.022	0.080	0.018	0.282	0.778	-0.134	0.179
	Influence from policy and legislation	-0.044	0.064	-0.041	-0.693	0.489	-0.170	0.082

* Dependent Variable: Prospective Value

V. CONCLUSIONS AND FUTURE WORK

The establishment of an index system plays a very important role in the evaluation of a brownfield redevelopment project. Based on the current situation of brownfields in China and the requirements of sustainable development, we put forth an index system for the evaluation of brownfield redevelopment, which includes the four dimensions of Societal and Economic, Financial and Accounting, Environmental and Health, and Prospective Value. Each dimension has some detailed criteria, which makes the index system more specific and applicable. The reliability and satisfaction of the index system is proven by reliability coefficients (Cronbach's alpha) and one–sample t-test. Also, the driving forces of each dimension are identified through multiple regressions. This work paves the way for the upcoming task of criteria weighting.

Future work can be pursued on two fronts. One is to test, validate and then improve the proposed index system through the employment of a case study. The other is to establish whether different stakeholders have different opinions on the driving forces of each dimension, so that we can get a clearer picture about the preferences of the different stakeholders while they make decisions.

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