The Evaluation Index Selection System for Sustainable Development: Based on Co-Word Network Method

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Abstract: This paper provides an evaluation index selection system for sustainable development (SD), which is more objective, flexible and dynamic. Keywords can be regarded as the consensus of the academics. A co-word network for SD can be constructed based on the co-word network method with keywords. The K-core filtration is a method to find vertices with the most structural importance. The SD network after the K-core filtration is regarded as the consensuses of the academics on the SD issue. Based on the filtered network, communities of vertices are detected. They are treated as the principle layer in the evaluation index selection system, while the vertices are treated as the domain layer. Further selection of vertices is needed to find those appropriate vertices with available factors to describe. The evaluation index selection system is built according to the selected vertices with principle layer, domain layer and factors. The normalized degree of a selected vertex to all selected vertices is the weight of the vertex. A case study of Daqing City is used to verify the effectiveness of the system. The result of the evaluation based on the proposed system shows a more promising further for SD.

1. Introduction

The evaluation of sustainable development (SD) is one of the most important way to assist governors to deal with the issues of sustainable development [1]. Since the concept of SD is of a broad range [2,3], the selection of SD evaluation indexes is significant and affects much of the evaluation results.

For any SD evaluation index system, it is required to reflect the essence and capability of SD about a specific region as possible as it could [4]. Limited by the systematic complexity, openness and nonlinear characters of SD and specific regions, it is not easy to decide the SD evaluation indexes in a scientific and objective way. Either the lack or the overlapping of information may lead to the incompleteness of the evaluation. A good evaluation system should be able to simplify the complexity of phenomenon, reflect the tendency of development and quantify the acquirable information [5,6]. Further, it should be suitable to apply on various regions. The selection of SD evaluation indexes has been developing from its naive age. However, many evaluation indexes are selected by views of experts and treated with principle component analysis. Whether the selection

of indexes could appropriately build a broadly suited system is still challenging [4,7,8]. There still lacks an index selection system to help systematically select appropriate indexes for different subjects.

The development of scientific literature database and scientometrics provides a potential way to build such system. Scientometrics uses explicitly defined approaches to give quantitative results and discussions [9]. Usually, this method calls for a database abundant in literature. Web of Science, which is one of the most prosperous database could provide enough amount of literatures to meet the demand [10]. The consensuses of a broad range of researchers and experts, which can be represented by the keywords of literature [2,11], could be refined from such database. Then, the co-word network method could be employed to analyse these consensuses. Using these consensuses, an index selection system could be built.

2. The Co-word Network Method

The co-word network uses couples of keywords to reflect the correlation among keywords. Based on this kind of correlation, clustering algorithms can be further applied to detect community structures where keywords are more closely related. Since the selection of keywords is self-organized by the academics, the communities can be regarded as the structure of a specific field [11].

In this research, "sustainable development" with quotation marks is selected as the search topic. The search is in a time range from year 1998 to 2016. 14,752 articles, which contains keywords are yielded. There are 28,588 unique keywords in total, which can be interpreted as 28,588 vertices in the co-word network. Keywords in one article would form a mutual connected graph. If a keyword is especially preferred by authors, it will appear in more articles. Consequently, such keywords will obtain more connections, which increase the degree of the corresponding vertices. To more clearly expose the consensuses in SD field, two related keywords are eliminated from the set, which are "sustainable development" and "sustainability". It is considered that these two keywords are right the aim, which is not suitable to exist in the set for describing them. Using software "Bibexcel" and "Gephi", the co-word network of SD field is ultimately constructed and visualized. Due to the large scale of the network, it is difficult to refine the great consensuses. Consequently, the K-core filtration is used to further simplify the network and expose the kernel consensuses [11]:

i) A node with a degree < k is removed along with its adjacent edges;

ii) Amongst the remaining nodes, those that fit condition i) are also removed until no node has degree less than k.

The maximum k value is 24. 7 communities containing 172 vertices are obtained after running the clustering algorithm [12]. This co-word network is the basis of the index selection system.

3. The Selection of Indexes and Determination of Weights

The reserved network after K-core filtration is regarded as the set of the widely accepted consensuses in SD field. Every community is defined as a principle layer and attached with a description, which includes "human activities and environmental characters", "education", "resource and its utilization", "energy and its utilization", "public awareness and social cooperation", "decision and management" and "social-ecological impact" (Table 1). Vertices in each community are regarded as the domain layer to be the connotation of the community. Furthermore, according to the availability of the elements in the domain layer, some available indicators in social system are suggested as the quantification factor. The weight of each factor are the normalized degree of the corresponding vertex or vertices.

Table 1: Evaluation index selection system for sustainable development [13].

Label		Degree	Principle layer (weight)	Factor	Weight
1-1	Agriculture	126	Human activities and environmental characters (0.248)	Agricultural Income Percentage and Agricultural Land Percentage	0.115
1-2	Poverty	119		GDP, GDP per capita	0.108
1-3	Rural development	88		Arable land area per capita and net average income of farmers	0.080
1-4	Economic development	264		Annual growth rate of GDP	0.240
	Economics				
	Economy				
	Economic growth				
1-5	Food security	71		Food storage	0.065
1-6	Gender	68		Population and gender ratio	0.062
1-7	Water management	135		Sewage Discharge and Sewage Treatment Rate	0.123
	Water resource management				
1-8	Natural resource management	62		Reserves, development and utilization of resources, import and guarantee of resources, destruction and degradation of resources	0.056
1-9	Forestry	60		Ratio of forestry output	0.055
1-10	Groundwater	53		Groundwater per capita	0.048
1-11	Environmental governance	53		The proportion of investment in environment	0.048
2-1	Education	130	Education (0.086)	Educational Level of Labor	0.340
2-2	Higher education	94		Higher education level	0.246
2-3	Environmental education	91		Environmental education level	0.238
2-4	Universities	67		Number of Universities	0.175
3-1	Land use	125	Resource and resource utilization (0.137)	Land utilization rate	0.205
3-2	Water resource	189		Total water resources storage, water resources per capita	0.310
	Water				
3-3	Urbanization	88		Urbanization level	0.145
3-4	Energy consumption	81		Elasticity Coefficient of Energy Consumption, Total Energy Consumption, Total Energy Production	0.133
3-5	Environmental protection	66		The proportion of investment in environmental protection projects	0.108
3-6	Water quality	60		Production capacity of tap water	0.099
4-1	Renewable energy	133	Energy and energy utilization (0.088)	Renewable Energy Types and storage	0.342
4-2	Energy efficiency	106		Utilization ratio of resources	0.272
4-3	Waste management	80		Disposal Rate and Utilization Rate of Industrial Waste	0.206
4-4	Cleaner production	70		The use of clean energy, advanced technology and equipment and pollutants production in Enterprises	0.180
5-1	Innovation	179	Public awareness and social cooperation (0.194)	The investment of innovation	0.208
5-2	Corporate social responsibility	156		Corporate Social Contribution	0.181
5-3	Environmental policy	151		Environmental policy in use	0.175
5-4	Mining	94		Degree of Mineral Resources Reserve, Exploitation and Proportion	0.109
5-5	Quality of life	71		Engel's coefficient, disposable income per capita, number of doctors per 10,000 people, air quality, social security coverage	0.082

5-7	Public health Health	106		Total health expenditure, the average population burden per hospital	0.123
5-6	Green economy	53		Income Ratio of Green Industry	0.061
5-8	Well-being	52		Happiness indexes	0.060
6-1	Environment	348	Governance and management (0.132)	Development of environmental disciplines	0.594
6-2	Natural resource	94		Freshwater, land and mineral resources	0.160
6-3	Pollution	81		Air pollution (sulfur dioxide) and water pollution (industrial wastewater discharge up to standard rate) condition	0.138
6-4	Infrastructure	63		Number of medical places, number of buses every 10,000 people, power generation, public green space per capita	0.108
7-1	Biodiversity	163	Social-ecological impact (0.115)	Bio-diversity	0.318
7-2	Tourism Ecotourism Sustainable tourism	208		Tourism Income	0.406
7-3	Protected areas	74		Number and area of nature reserves	0.145
7-4	Forest	67		Forest area, forest coverage and forest stock	0.131

It has to be claimed that Table 1 does not contain all the vertices. It is because in the field of SD, although some keywords like "China" and "indicator" are widely preferred and acknowledged, they are not appropriate enough to be evaluation indexes due to their conceptual characters and difficulty in quantification. Such index selection system is convenient to select appropriate indexes (or combination of indexes) according to real conditions. Moreover, such system is a dynamically evolving system, which follows the progress of the most researchers to overcome the incompleteness of individuals.

4. The Application of the Index Selection System

Based on the research by Wang [7], this paper proposed how to use the proposed system. According to Table 4-1 in Wang's research, the principle layer and the domain layer are set the same in this application (Table 2). The next step is to substitute the factors with the factors in the selection system. Then the weight of each factor is assigned the corresponding value in Table 2. The weight of the principle layer can be calculated according to the related factors. Using the data provided in Wang's research, the score of each factor can be calculated by multiplying the weight with the data value. In this way, all the scores can be calculated. The product, which is the sum of factors' scores in a principle layer multiply the weight of the principle layer is the score of the principle layer. The sum score of the principle layers will be the score of evaluation.

Table 2: The reset of the evaluation indexes and their weights for Daqing City [13].

Target	Principle Layer	Domain Layer	Factor	Weight
Evaluation of sustainable development	Society (0.433)	Life quality	1-2,1-5,3-1,5-5,5-7,6-3	0.112
		Infrastructure	6-4	0.017
		Science and education level	2-1,5-1	0.085
		Social Structure	1-3,3-3	0.035
		Society security	4-4,5-2	0.056
		Population	1-6	0.010

		Population diathesis	2-1,2-2,2-4	0.118
	Environment (0.297)	Environmental pollution	3-5,3-6,4-3,6-1,6-3	0.178
		Economical construction	5-3,7-1,7-3,7-4	0.119
	Resources (0.108)	Living resources	1-1,1-9,1-10,3-2	0.082
		Mineral resources	1-8,5-4	0.026
	Economy (0.163)	Economic scale	1-4,5-6,3-4,4-1,4-2*	0.163
		Industrial structure		
		Economic benefit		
		Intensive economy		
		Extrovert economy		
		Economic impetus		
		Economic prosperity		

* The concepts are too related to correspond respectively like the others. They are treated together as a whole part.

As a contrast to the score by Wang in Table 3, the evaluation score based on Table 2 is listed in Table 4. The weight of principle layer in Wang's research is equally distributed. However, after selecting factors in the system, the weight of each principle layer has changed. This means distributing the same importance of each supporting system is not appropriate enough to reflect the degree of SD for a given region. In another aspect, how much degree does the society develops affects more on the SD than the economy, environment, and resources. That is to say, whether a region or a society could reveal SD depends more on the social development level, which depends more on human ourselves.

Table 3: The score of evaluation for Daqing City in the paper.

Year	Society	Rank	Economy	Rank	Environment	Rank	Resource	Rank	Total Score	Rank
1999	-0.5519	5	-0.2078	3	-0.7149	5	0.7269	2	-0.1868	5
2000	-0.402	4	-0.4875	5	0.1938	3	0.7385	1	0.009	2
2001	-0.115	3	-0.3531	4	0.654	1	-0.2208	3	-0.0057	3
2002	0.0567	2	-0.0505	2	0.3242	2	-0.5763	5	-0.0604	4
2003	1.0121	1	1.0961	1	-0.4571	4	-0.5167	4	0.2053	1

Table 4: The score of evaluation for Daqing City based on the evaluation index selection system [13].

Year	Society	Rank	Economy	Rank	Environment	Rank	Resource	Rank	Total Score	Rank
1999	-0.04	3	-0.8461	5	-0.2114	5	0.1015	1	-0.1847	5
2000	-0.2433	5	-0.2138	4	0.0326	3	0.0855	2	-0.1235	4
2001	-0.0647	4	-0.0934	3	0.1166	1	-0.0034	3	-0.0143	3
2002	0.0987	2	0.1507	2	0.0754	2	-0.0821	4	0.0758	2
2003	0.2493	1	0.8595	1	-0.0132	4	-0.1015	5	0.2253	1

The constant rising score of the evaluation proof an exciting result, which is the capability of SD in Daqing City is being stronger. The result of our evaluation gives a more promising future of development. It is credible to believe SD can be achieved by the endeavour of all aspects.

5. Conclusion

In this paper, the co-word network method is introduced to build the evaluation index selection system for SD. The case of Daqing City verifies the effectiveness of the system and provide a different but hopeful result from the original research. This system is an explicitly defined, dynamically evolving and academically based system, which could be flexibly used to different economy-society-nature system.

However, as an exploratory attempt, there are still limitations. Some elements in the domain layer, such as “happiness”, “environment”, “indicator”, etc., are hard to describe quantitatively or qualitatively. This will lead to the involuntary ignorance of the elements. Moreover, the selection of the factors in the case study is affected by the views of individuals, which is not totally objective. Although there are still limitations, we are expecting the progress of the whole world, one day, could better describe these elements by any possible factors. And it is believed such kind of system can be a potential way to better evaluate and achieve SD goals.

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