Establishment of Assessment Indicator System of Sustainable Development in Mining Industry and Evaluation of Pilot Project

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Abstract. The economy relies heavily on resources in China, which is particularly evident in resource-based cities where the resources industry takes up a high proportion in economic structure. The local mining industry affects or determines all social and economic aspects of the area. Whether the mining industry can achieve sustainability decides the future development of the region. This paper analyzes the fundamental implications of sustainability of mining industry from two logic perspectives, i.e. the economic and social development stages and microcosmic enterprises. We review the evaluation system of sustainable development of mining industry and establish an evaluation indicator system which covers four sub-objectives and 21 indicators. On the basis of feasibility principles, the lateral and vertical evaluations on the sustainability are performed on 8 resource-based cities including Jiaozuo. Being consistent with the actual situations, the conclusion has reference value for making policies.

Introduction

Mining industry belongs to resource-based industries and is also core part of resource-based industries. The mining industry technically refers to an industry for which the natural resources with non-renewable attributes and “dot form” distribution are production objects and raw material products are the output for the economic organization [1]. China's economy is characterized for being resource-dependent. One of the evidences lies in a high proportion of resource-based cities, accounting for 34% with 90 out of 265 prefecture-level cities. Among 393 county-level cities, there are 90 of them are resource-based cities, accounting for 18%. Therefore, whether the mining industry can have sustainable development are crucial to the economic performances, social stabilities and environmental protection in specific cities and regions. How to objectively and effectively evaluate the sustainable development of mining industry has become the hotspot and focus in academic research and has been a concern of businessmen.

Definition of sustainable development of mining industry

Sustainable development is featured with four principles, i.e. fairness, sustainability, commonality and expansibility [2]. The sustainable development of the mining industry should be defined in a scientific and objective way on the basis of the four principles and by taking into account of the characteristics and patterns. Only by doing so can be of use for universal theoretical guidance on the development of the mining industry. Only when integrating the sustainable development with mining industry on the basis of essential attributes and summing up the law for sustainable development of mining industry can we develop an objective and scientific evaluation system for sustainable development and provide meaningful guidance for the development direction and prospects.

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The economic structures have experienced regular changes as the economic develop level advances ever since the industrial society came. As to the types of industry, there are the following changes:

Table 1: Matching table of stage of economic development and type of industry

Stage of economic development	Average GDP per capita	Industrial characteristics	Added value changes
Industrial initial stage	Less than 1000 dollars	Basic (raw material) industry	Growing from up down
Industrial growing stage	2000-4000 dollars	Machining (assembly) industry	
Industrial mature stage	6000-8000 dollars	Precision (chemical) industry	
Post-industrial stage	More than 10,000 dollars	Service industry	

The position of mining industry for being basic and raw material determines the stage characteristics of its sustainable development. Meanwhile, such stage characteristics are not only about the time. To be more specific, the sustainable development of mining industry depends primarily on the extent of the local economic and social needs. When the local economy and society need the support of sustainable development of mining industry, this will be the external drive towards such goal, mainly gaining the external supports for the development of mining industry. Then the sustainable development of mining industry also relies on the extent of positive operation, which is the internal motivation to achieve sustainable development. It's mainly indicated in the resource utilization level in mining entities, functional management level and profit models.

The mining industry is classified in meso-ecnomics and its microscopic constitutions are mining enterprises [3]. These mining enterprises are economic units with independent legal representative. There are three ways available for mining enterprises if their development is analyzed according to the organizational life-cycle theory. The first one is going through the single product phase, single series of products phase, single area production phase, diversified production phase and capital operation phase. The general trend is to spread business risks and pursue the business areas with high added value so as to completely withdraw from entity management for capital operation. The second way is to search for new resources in other regions or other countries as the operation mode gets mature and the local resource reserve declines. The mature operation mode of mining companies can be copied in the continuous location. The third way is to combine the above two ways.

From these perspectives to see the sustainable development of mining industry, there are three things to consider. The first one is the local resource reserve is no longer all of the influencing factors to the sustainable development of mining industry. The resource isn't limited to the local area. The dependence on the continuous resource becomes larger gradually. Secondly, the key deciding factor for sustainable development of the mining industry lies in whether the enterprises have sound operation, which refers to profit model and management model. If they don't have good profit model or management model, they will soon be under restructure or acquisition by outside mining enterprises. Thirdly, the profit brought by mining enterprises determines the expansion ability to their business areas. If the marginal benefits are higher than mining and they have the capability to open new markets, they will definitely transfer the means of production to areas with relatively high marginal benefits in order to obtain greater benefits. Therefore, if the ability to absorb other industries is stronger than resource development, the local resource development will be squeezed out. Its economic and social contribution will drop. They have to turn to other continuous resource development. Conversely, the local resource development will be enhanced under the economic and social pressures. Then the external and internal drives will be needed to ensure the sustainable and long-term development.

Choose proper evaluation system for sustainable development of mining industry

All practical activities of humans can't do without the guidance and support of theories [4]. It's also true for the sustainable development of the mining industry. The theorists in sustainable development have been very active, even though the complete theoretical system hasn't been developed. However, the relevant basic theory studies have been successful to certain degree by using economics, management science, ecology, urban studies and sociology. The theoretical knowledge must be involved to solve the economic, resource, environmental and social problems concerning sustainable development of mining industry. Attention should be paid to the cross-disciplinary information to gain more insights into the sustainable development and theoretically get a thorough exposition to these problems.

Sustainable development theory

Sustainable development is created when the tradition extensive and predatory development has escalated disputes with ecological demands and suffers from bottlenecks. It is the fundamental change for the modern development concept [5]. During the transformation, we started to realize that the former economical development models had irreversible impacts on resource exploitation and environmental degradation, which is "unsustainable." As a result, new ideas and concepts are proposed, such as "development that meets the requirements of the environment","development without destroying the environment", "eco-development" and "continuous or sustainable development", which finally lead to the "sustainable development" [6]. It's gradually introduced in various fields and has respective interpretations.

Life-cycle theory

According to the life-cycle theory of American scholar Raymond Vernon, a product goes through introduction, growth, maturity, saturation and decline from entering the market to being phased out [7]. Such life-cycle theory also applies to the mining industry, which also has to experiences the whole cycle. It also foresees the fate of the resource-dominated cities. American geologist Hubert divided the life cycle of the mining into four stages: (l) Preparation: the resource is still waiting to be exploited in this stage when infrastructures are being built and exploitation plans are being made. (2) Growth: exploitation facilities are in full operation and the amount of resource development has continued to rise. (3) Maturity: the resource development reaches a certain scale and relevant industries are booming and industrial clusters are formed driven by the resource industry. (4) Decline: for the limitation that the resource is non-renewable and the relevant industries meet with development bottlenecks in urgent need of new continuous and alternate industries to ensure the steady growth of the local economy. Otherwise, the region will begin to decline and disappear.

The cities that rely on the resource exploitation will have similar life cycle from introduction, growth, maturity to decline. If the resource-dependant cities seize the opportunities of the growing and maturing period of resource-based industries to make full use of the fortune, technology and talents brought by resource development in their long-term strategy, they will be able to develop other related industries and service industry and positively cultivate new continuous and alternate industries. Consequently, when the resource-based industry is facing bottlenecks, mutual benefits among different industries will be able to help each other for the purpose of economic steady and sustainable development, achieving easily the resource continuity and industry replacement [8]. In this way, before exhausting the resource, there will be sufficient economic development potentials and growth engines to support the long-lasting economic growth.

The resource-based cities can be classified into two types based on which comes first, the city or the resource: "resource-based industry before city" and "city before resource-based industry". The former mainly means that the exploitation of resources promote the local economic development and lead to prosperity, thus forming a resource-based city with advantages in resources. The latter indicates that the discovery and development of resources are later than the formation of a city, which then the local economy is further promoted to a higher level. No matter which kind of city it is, there are two options available when it comes to resource depletion and resource-based industry

is unable to support the local economic development: i.e. transformation or decline. Considering the special political, economic and cultural influences on neighboring areas, it's more reasonable to choose transformation for most of cities. By finding new continuous industries and getting rid of the rigid resource supply and demand to avoid conflict intensification with sustainable economic development, the resource-based cities will gain a new life.

The Interindustry Relation Theory

The Interindustry Relation Theory propped by the American economist Wassily W. Leontief points out the intricate technical and economic relevance existing between the various industries within a specific area. As to the various industries within a specific country or region, the industry with the strongly relevance is generally considered as the dominate industry. The stronger the relevance degree it has, the larger drive it will exert on the economic growth for the area. Therefore, priorities should be given to the industry with larger force to stimulate and promote the economic development.

Industrial development and optimization theory

Industrial development, the final goal for industrial studies, refers to the necessary conditions and environment required during the introduction, growth, expansion, recession and elimination. Therefore, policies and measures should be taken from macro policy perspective to promote the development and growth of related industries. The prosperity in a single industry and the industrial cluster is the development of the industry. The structural optimization is to improve the efficiency and level and optimize the economic benefits by changing the interindustry configuration and proportion. Rather than focus on a few efficient industries, any country or region should establish an industrial cluster which is compact, efficient and coordinative and brings high economic benefits centering on one efficient industry so as to ensure the steady and sustainable development for the national or regional industrial economy.

A majority of our resource-based cities have long depended on a single mining industry, leading to the deformity in industrial and social structure. Other industries don't have the basic development environment. Even if they are built under the support of government, they don't have the capacity for self-development, not to speak to provide strong support for the economy. This is just like an ecosystem. Only the biological diversity can guarantee the vitality of the system. Higher maintenance cost is required for the single green turf.

Establishment of the evaluation indicator system for the sustainable development of mining industry

According to the relevant literature in the sustainable development evaluation in mining industry, the evaluation indicator system is named as sustainability degree of mining industry (SDMI) to describe the sustainable status. The overall objective is divided into sub-goals for economy, environment and development support, each of which contains several indicators [9].

The degree of sustainable development is defined between 0 and 1. According to the cask theory, the degree of sustainable development (SDMI) of overall objective is equal to the minimum value (of the sustainable development degree of industrial economy sub-goal, industrial environment sub-goal, industrial development support sub-goal and industrial development strength sub-goal) [10]. That is to say sustainable development degree of overall objective is the lowest value of the sub-goals.

The scores of sub-goals are given by experts. The influence factors of one sub-goal are compared pairwise. The qualitative comparison is transformed into quantitative matrix within a scale of 1 to 9 to determine the weight of each indicator [11].

The indicator assignments are extracted from the city statistical yearbook. In case there is no indicator or it is missing, the provincial yearbook is used instead.

The indicator assignments have forward and reverse indicators. The reverse indicator is the difference of current value minus the maximum value divided by the difference of minimum value

minus maximum value. The forward indicator is the difference of current value minus the minimum value divided by the difference of value maximum minus minimum value [11].

Table 2: Evaluation indicator system for the sustainable development of mining industry

Overall Objective	Sub-goal	Indicator	Remarks
Sustainability degree of mining industry	Industrial economy	GDP	Y1
		Local financial revenue	Y2
		Average production value per ten thousand capita	X1
		Percentage of hi-tech industries in GDP	Y3
		Energy consumption per ten thousand in GDP	X2
		Water consumption per ten thousand in GDP	X3
		Percentage of R&D investment in GDP	Y4
	Industrial environment	Industrial wastewater discharge volume	Y5
		Industrial wastewater discharge pass rate	X4
		Smoke discharge volume	Y7
		Smoke removal volume	Y8
		Geological environment management rate of mine	X5
	Industrial development supports	Number of employees	X6
		Road area per capita	X7
		Power capacity per capita	X8
		Water resources quantity per capita	X9
	Industrial development strength	Mine industrial concentration	X10
		Proportion of output value of large-scale mining enterprises	X11
		Proportion of profit of large-scale mining enterprises	X12
		Local supplementary amount	X13
		Supplementary amount of continuous resource	X14

The forward indicators are positively related to the sustainable development of mining industry, mainly including average production value per ten thousand capita, energy consumption per ten thousand in GDP, water consumption per ten thousand in GDP, geological environment management rate of mine, number of employees, road area per capita, power capacity per capita, water resources quantity per capita, mine industrial concentration, proportion of output value of large-scale mining enterprises, proportion of profit of large-scale mining enterprises, local supplementary amount and supplementary amount of continuous resource.

The reverse indicators are negatively related to the sustainable development, mainly including GDP, local financial revenue, percentage of hi-tech industries in GDP, percentage of R&D investment in GDP, industrial wastewater discharge volume, industrial wastewater discharge pass rate, smoke discharge volume, smoke removal volume and social security coverage rate.

The sustainability degree of the sub-goal can be calculated by the following formula:

The sustainability degree of the sub-goal = Σ indicator scores × indicator weights

Pilot assessment

The typical resource-based cities are selected for assessment in two dimensions. One is lateral evaluation when data from a specific year (2010) are chosen to compare the sustainable development of mining industry. The other is vertical evaluation when the sustainable development of one city is compared to get an insight into the development trend.

According to the scores provided by experts, the indicator weight is calculated.

Data in 2010 from eight resource-based cities, including Jiaozuo, are chosen for evaluation. Due to the fact that there is data concerning the industrial development strength, evaluation is made only on the first three sub-goals. The result is shown in the table below.

Table 3: Calculation table of the sustainable development degree of typical cities

Indicator	Jiaozuo	Pingxiang	Fuxin	Liaoyuan	Panjin	Shizuishan	Tongling	Fushun
Economy subtotal	0.38	0.28	0.36	0.28	0.17	0.43	0.35	0.38
Environment subtotal	0.52	0.44	0.36	0.24	0.39	0.38	0.73	0.80
Development support subtotal	0.01	0.09	0.11	0.22	0.63	0.24	0.11	0.14
Sustainable development degree	0.01	0.09	0.11	0.22	0.17	0.24	0.11	0.14

Judging from the sustainable development degrees of each resource-based citt calculated from the provincial statistical yearbook and indicator weights, the sustainable development degrees are quite low. All of them are caused by insufficient support. Therefore, it's critical to have policy supports. The sub-goals of each city have poor development balance, resulting in low sustainability degree. The environment sub-goal of each city is quite high, which mainly benefits from the evident increase in investment in environment and in the awareness of environmental protection ever since the establishment of transformation policy. However, the economic pressure still lingers in several cities, which indicates that policy support is needed to improve the operation of mining industry to support or foster the core competition and improve the sustainability degree.

Table 4: The result of sustainability degree measurement of Anwei Tongling mining industry

Year	Economy	Environment	Development support	Sustainability degree of mining industry
2010	0.45	0.22	0.25	0.22
2009	0.32	0.20	0.25	0.20
2008	0.39	0.20	0.24	0.20
2007	0.44	0.54	0.21	0.21
2006	0.43	0.57	0.07	0.07

It can be seen from the result that the sustainable development degree has been improved from 2006 to 2010. It indicates that the transformation policy has worked in Tongling. However, environment and economic development support are strong constraining forces to the sustainable development of mining industry. Environment in particular worsens significantly. The environmental issues have been in huge debt in history for a mining city of Tongling. Even if there is growing investment in environment, the new economic development demands still have immense

inertia effects. As to economy sub-goal, the demands to mining industry are high. It indicates that the economic transformation needs the continuous contribution from mining industry in Tongling to provide financial security for other industries and buy time for their development. At the same time, the mining enterprises have mature and effective management model and profit model.

Table 5: The result of sustainability degree measurement of Shizuishan mining industry

Year	Economy	Environment	Development support	Sustainability degree of mining industry
2010	0.39	0.11	0.18	0.11
2009	0.41	0.81	0.11	0.11
2008	0.43	0.83	0.35	0.35
2007	0.40	0.74	0.37	0.37
2006	0.38	0.89	0.40	0.38

Judging from the result, the sustainable development degree keeps declining from 2006 to 2010 in Shizuishan, which is opposite to Tongling. Even though the economy keeps steady, the environment and development supports have obvious decline. The data is consistent with the conclusion of field research. Shizuishan is located in the west which is drought and has little rain. What makes thing worse is over decades of exploitation in subcutaneous layer. The local environment is extremely harsh under natural and human pressures. Shizuishan has long been supported only by resource industry. The curse of resource is evident with imperfect urban functions and scatter and lagging urban infrastructures. All of these have enormous restrictions on the industrial development.

It's well known that China's economy is still in industrial stage and resource-based industry is still the important part for the local economy. Resource industry still stays a high proportion in the economic structure in resource-dependant cities. Therefore, whether the local mining industry can achieve sound operation is critical to the sustainable development of the local economy and society. It will be the solid foundation for the establishment of local economic and social policies to objectively evaluate the sustainable development of mining industry.

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