A DYNAMICAL SYSTEM STUDY FOR THE ECOLOGICAL DEVELOPMENT OF MINERAL RESOURCES IN MINORITY AREAS

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ABSTRACT. The distribution of mineral resources in China is mainly concentrated in minority areas. However, the technology of mineral resources development in minority areas is relatively backward and the utilization rate isn’t high. Unreasonable exploitation for mineral resources has caused tremendous damage of mining environment, which restricts the sustainable, healthy and stable development of mining areas. Therefore, how to construct the ecological industrial chain of mineral resources in minority areas has become an important issue of mining sustainable development. In this paper, a SD model with the characteristic of minority areas is established by constructing the dynamical system flowchart that takes mineral resources-environment-economy-society (MEES system) as the main research object based on system dynamics simulation, combination determining weights, and fuzzy sets, etc. In addition, taking Tibetan minority areas for an example, this paper predicts the tendency of the MEES system in the region. Meanwhile, this paper designs four different development modes to provide the operable choice and reference for exploiting the mineral resources in minority areas.

1. Introduction. China is a unified multi-ethnic country. Although the people of minorities have taken the low proportion of the population since ancient times, their inhabited areas account for 64 percent of the national areas. These broad land contain plenty of natural resources, have huge economic development prospects, and lay a solid foundation for the development of China as well. In recent years, however, due to the lack of capital, technology and talents, the minority areas in China didn’t transform perfectly the advantaged resource into economic advantage, instead of the local ecological environment that suffered serious damage. The main reason is that the exploitation of mineral resources in the minority areas is extensive and that exists many problems.

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How to make exploitation and utilization of mineral resources reasonably has been a hot topic in academic research. In the early part of the study, some scholars advocated that the development of mineral resources should be drawn to the direction of circular economy, and put forward the principle of “reduction, reuse and recycling” (3R) to improve the mining efficiency of the ore [14][5]. After that, scholars have creatively combined the development of circular economy with the simultaneous exploitation of low-grade and high ore to carry out more specifically the circular economy policy[13]. They considered that the pattern of circular economy was the only way to realize sustainable development of mining industry. And the development and utilization of mineral resources at different hierarchies should be respectively taken their development mode[18], to excogitate the evaluation indicator system and model of circular economy in mining industry in China[11][7]. Then some scholars put forward cluster development model of local mineral resources industry[28]. At the same time, other scholars focused on the optimization of the mineral resources industry chain and established the environmental-friendly mineral resources industry chain by applying the supply chain theory to the mineral resources industry[4]. In addition, the development direction of mining industry and the evaluation of mineral resources have also been discussed. For example, taking the dynamics and global trends in the economy of raw material into the consideration of the demand of mineral resources and presenting main assumptions that relate to the sustainable development of the mining sector[2]. Proposing practices for sustainable supply chain management for minerals, deriving the research directions for the future development of the field[10], summarizing 80 deposit models for known ore deposits to estimate the total (known and unknown) resources available and mineral types for 25 of the most perspective strategic minerals located in China, and developing a new suite of tool for mineral resource assessment[19], constructing and discussing the prediction models for mineral resources and presenting 12 models used for mineral assessments [26]. Also, mineral resources, by-products and associated resources of mineral resources development and utilization, and resources of the non-mining industry and land resources were used as material bases, respectively executed vertical integration, horizontal integration and hybrid integration for the ecological industry chain, and proposed that integrated path and mode of ecological industry chain in the development and utilization of mineral resources in the mining areas[12]. Then the relevant scholars put forward that industrial chain should be established, taking large enterprise groups as the core by market mechanism. And mineral resources development and integration should be considered comprehensively from the perspective of resources, enterprise management and order of mining development[1], thus the sustainable development of mineral resources industry was realized[27]. With the rapid development of China’s economy and increasing consumption of natural resources, the scholars gave the perspective of ecological economics in our country and proclaimed by adopting evaluation method of the “energy” and “green GDP”, comprehensive and green evaluation indicators system of mining industry should be established in a more comprehensive perspective [9][17]. Later, some scholars deepened again the idea of circular economy. According to the connotations and characteristics of circular economy, they analyzed indicator system of circular economy, ascertained the low-carbon quality of circular economy and illuminated the dilemma of the theory of circular economy. Based on the comprehensive and integrated perspective, they elaborated the systematic characteristics of the low-carbon, comprehensive and integrated model of circular
economy from three aspects of the overall characteristics, structure of pattern and operational mode. From the theoretical basis, system and innovation, comprehensive and integrated theoretical framework of low-carbon model was proposed[20]. Based on the original 3R principle, the principle of 5R is put forward with the addition of the principle of open source and renewal[22]. In recent years, with the constant progress of science and technology, more and more scholars focused on the ability of technical innovation for China’s mineral resources industry, by using the nonparametric kernel density estimation, markov chain analysis model and tobit regression analysis model, and concluded that the mineral resources industry at the present stage in China urgently would need a transformation into the scientific and technology-driven industry[21][24]. Along with the continuously deepening of research, scholars switched their views to the minority areas with rich mineral resources in China, and put forward the compensation mechanism of development of mineral resources in minority areas that was timely with the addition of ecological compensation and humanistic compensation based on the existing mechanism[8][16].

Most predecessors researched how to optimize ecological chain of exploitation of mineral resources. Related to more theoretical component and lighter qualitative or quantitative part, and there are few researches on mineral resources in minority areas of China. Based on this problem, this paper constructs a dynamical system, takes the minority region as the research object, delimits the system boundary, builds macroscopically MEES system with characteristics of minority nationality areas, and depicts complicated correlations of the MEES subsystems to simulate the development of minority areas in the future, finds out the relationship and coordination function with each element. In addition, decision support is provided for regulating policies of the minority management and planning future goals through the sensitivity analysis.

2. Research area and methodology.

2.1. **Research area.** Most of the ethnic minority areas are located in the western border areas of China, because its rich mineral species and huge mineral reserves have become an important mineral resources development in China. In recent years, due to carrying out the policy of closing the land for reforestation in the minority areas in China, the local people focused on the underground mineral resources, causing the mining developing rapidly, which had driven the local economy to get prompt development. Taking the economic development of minority areas in 2013 as an example, the gross domestic product (GDP) of minority areas reached 6477.2 billion yuan, rising by 10.6 percent over the previous year. Announced financial budget revenue of minority areas reached 843.5 billion yuan and accomplished an increase of 13.1 percent compared with last year[3]. However, due to the serious illegal mining and immature exploitation technology, the model of predatory exploitation was mostly operated, meanwhile, the particular natural environment of ethnic minorities and fragile ecological environment, caused serious damage to the environment, including series of increasing problems, like land occupation, vegetation deterioration, landforms and landscape devastation, secondary geological disaster, water resource destruction, air contamination and so on. These problems became restrictive factors for economic development of the minority areas and made a negative impact on harmony and stability of the minority areas.
2.2. Construction of ecological economic and social system for minority mineral resources exploitation. The exploitation of mineral resources in minority areas is a nonlinear, dynamic and open complex giant system composed of many elements of resources, environment, economy and society, so it is suitable for the research by using system dynamics. This article optimizes the model based on the predecessors, it chooses four subsystems of resources-economy-environment-society and integrates the particularity of minority areas, and puts four subsystems in a reasonable way together, to build an eco-economic and social system of mineral resources with the characteristics of minority areas. Therefore, the establishment of ecological and economic system of mineral resources in minority areas should firstly study the interrelations and internal relations between the mineral resources development[23], ecological and environmental protection, national economic development and national social progress in minority areas, and explore the balance point among the rational development of mineral resources in ethnic areas, ecological and environmental protection, the steady development of national economy, national social progress, and thus plan the best path and mode reasonably on development of mineral resources in minority areas.(See Figure 1)

![Figure 1. The relationship between mineral resources development, eco-economic and social systems in minority areas](image)

3. Establishment of simulation model for minority areas.

3.1. Boundaries of the system. According to the main principles of system boundary determination, the study involves the internal elements and entities of mineral resources, society, economic development and ecological environment, and determines the main variables to carry out the researches, and then tracks new variables, until there is no missing variables that have an important effect on the system.
3.2. **Selection of system indicators.** The construction of the indicator system for eco-economic and social system of mineral resources in minority areas is the most basic step in the study of minority mineral exploitation. Under the assumption of “eco-economic mind”, the four subsystems are interactive and inseparable organic, and based on the scientific, administrative, rational and feasible data[15][25], the paper constructs evaluation indicator system of mineral resources development in minority areas. The establishment of the five indicators with national mineral development policy, national fertility policy, cultural differences in ethnic areas, growth policy of national economy and policy of ethnic environmental improvement are due to the fact that minority areas have certain autonomy, thus making the indicator system more appropriate and consistent with the actual situation of minority areas. The part of indicators is shown below.(See Table 1, Table 2)

| Parameter name                                | Unit            |
|-----------------------------------------------|-----------------|
| Proven mineral reserves                       | $10^4$ tons     |
| Added proven reserves                         | $10^4$ tons / year|
| Impact factor of exploration influence        | non-dimension   |
| Added proven reserves for investment per unit | $10^4$ tons / $10^8$ yuan |
| Mining investment                             | $10^8$ yuan/year|
| Annual output                                 | $10^4$ tons     |
| Annual added output                           | $10^4$ tons / year|
| Impact factors of mining technology           | non-dimension   |
| National mineral development policy           | non-dimension   |
| Mining output value                           | $10^8$ yuan/year|

**Table 1.** Mineral resources indicators

| Parameter name                                | Unit            |
|-----------------------------------------------|-----------------|
| Discharge amount of wastewater                | $10^4$ tons     |
| Discharge of exhaust fumes                    | $10^4$ tons     |
| Discharge amount of solid waste               | $10^4$ tons     |
| Acreage of disrupted land                     | $10^4$ hectares |
| Environmental investment                      | $10^8$ yuan/year|
| Environmental pollution                       | non-dimension   |
| Policy of ethnic environmental improvement    | non-dimension   |
| Ratio of environmental investment in mining areas | %  |
| Environmental awareness                       | non-dimension   |

**Table 2.** Ecological environmental indicators

3.3. **Establishment of MEES system model.** According to the MEES system causal relationship diagram of the minority areas, the corresponding MEES system model is established.(See Figure 2)
Figure 2. The MEES system model.
4. Empirical analysis of Tibetan minority areas. Tibetan minority areas as China’s important mineral resources exploitation places, have made a strong contribution for China’s economic development. 101 mineral species have been found in Tibet, there are 41 kinds of proven mineral reserves, including mineral water, geothermal energy. Exploration results show that these ten dominant minerals in the country are chrome, copper, boron, lithium and other 17 kinds. In addition, gold, zinc lead, molybdenum, iron, platinum group metals and mineral water, oil and other non-metallic also have a broad prospect of exploration. However, due to the relatively complex geographical environment, vulnerable ecological environment, insufficient energy supply and poor transportation, the development of mineral resources in Tibet has been at a low level, coupled with the backward mining technology and the relatively scattered layout, resulting in a small pattern of mining in Tibet. At the same time, unreasonable exploitation also has brought serious environmental pollution problems making the local people’s survival and social production have a very serious distress which has seriously hampered the development of local economy.

4.1. Model parameters setting. The basic structure of system dynamics is information feedback. The behavior patterns and main results of the model depend on the model structure rather than the parameter value. Eco-economic and social system feedback mechanism of minority mineral resources exploitation is very complex, so that we select the variables that have significant influence on the state, the rate and the data which is relatively easy to implement as the main research object of the model. Table function is a unique function in system dynamics, and it is mainly used to solve the complex nonlinear relationship between the two variables, so lots of table function will be used in this article. The main methods to determine the parameters in the design model include:

(1) In order to find out the correlation between the variables, linear regression method is used to test whether there is a linear correlation between the variables by using SPSS 17.0, and it is believed that R-squared above 0.6 can illustrate that the variables have a strong linear correlation in the regression model with statistical significance.

Based on the regional GDP as the independent variable and the mining investment as the dependent variable, the linear equation is obtained as follows:

\[
\text{mining investment} = -194.304 + \text{regional GDP} \times 0.443, \text{ R-squared} = 0.932
\]

Based on the regional GDP as the independent variable and the environmental investment as the dependent variable, the linear equation is obtained as follows:

\[
\text{environmental investment} = 14.995 + \text{regional GDP} \times 0.027, \text{ R-squared} = 0.721
\]

(2) To predict the future development trend of some variables, the multi-attribute evaluation of the intuitionistic fuzzy set and the method of secondary combination weighting are applied to determine the value of these variables based on the Delphi method.

Assume that X is a nonempty set:

\[
P = \{ (x, B_p(x), C_p(x)) | x \in X \}
\] (1)

which is called an intuitionistic fuzzy set, where \( B_p(x) \) and \( C_p(x) \) are the membership and non-membership degrees of \( x \in P \), respectively,

\[
B_p : X \rightarrow [0, 1], x \in X \rightarrow B_p(x) \in [0, 1] \quad (2)
\]

\[
C_p : X \rightarrow [0, 1], x \in X \rightarrow C_p(x) \in [0, 1] \quad (3)
\]
Then we can get a combined weight vector sum: 

$$V = \frac{B_p(x)}{B_p(x) + C_p(x)}, \quad x \in X$$ (4)

The number of known experts is $n$, according to the relevant experts comprehensive evaluation of data set as $V = \{V_1, V_2, \cdots, V_m\}$, for each $V_i = B_i + C_i = n$. The support rate for each data $V_i$ is $B_i/n$, the opposition rate is $C_i/n$.

Here we define the weight $V_i = B_i/n$ of $V_i$ and it satisfies $\sum_{i=1}^{m} v_i = 1$. And then according to the experience of experts and professional degree, the experts are given the different weights, the weights of the experts who support the same data are added to the results: $\omega = \{\omega_1, \omega_2, \cdots, \omega_s\}$; and it satisfies: $\omega_1 + \omega_2 + \cdots + \omega_s = 1$; the weights determined are substituted into the following two models:

$$\mu_i = \frac{\mu_i \times \mu_{2i}}{\sum_{i=1}^{n} \mu_i \times \mu_{2i}}$$

$$\mu_i = 1/2(\mu_i \times \mu_{2i})$$ (5)

Then we can get a combined weight vector sum: $U^1 = (\mu_1^{(1)}, \mu_2^{(1)}, \cdots, \mu_n^{(1)})$ and $U^2 = (\mu_1^{(2)}, \mu_2^{(2)}, \cdots, \mu_n^{(2)})$, and construct the optimal combination weight vector $U^* = (\mu_1^*, \mu_2^*, \cdots, \mu_n^*)$, $\sum_{i=1}^{n} \mu_i^* = 1, i = 1, 2, \cdots, n$, among them, $\mu_i^* = \lambda_1 \mu_i^{(1)} + \lambda_2 \mu_i^{(2)}, i = 1, 2, \cdots, n$, then:

$$\begin{cases}
U^* - U^1 = (\mu_1^* - \mu_1^{(1)}, \mu_2^* - \mu_2^{(1)}, \cdots, \mu_n^* - \mu_n^{(1)}) \\
U^* - U^2 = (\mu_1^* - \mu_1^{(2)}, \mu_2^* - \mu_2^{(2)}, \cdots, \mu_n^* - \mu_n^{(2)})
\end{cases}$$ (6)

According to the minimum principle of deviation weight, the following nonlinear optimization model is constructed:

$$\begin{cases}
\min \sum_{i=1}^{n} \|U^* - U^k\| = \min \sum_{i=1}^{n} (U_i^* - U_i^k)^2 \\
= \min \sum_{i=1}^{n} (\lambda_1 \mu_i^{(1)} + \lambda_2 \mu_i^{(2)} - \mu_i^{(k)})^2 \quad s.t. \sum_{i=1}^{n} \mu_i = 1
\end{cases}$$ (7)

The nonlinear optimization model is solved to construct the Lagrangian function:

$$L(\lambda_1, \lambda_2, N) = \sum_{i=1}^{n} (\lambda_1 \mu_i^{(1)} + \lambda_2 \mu_i^{(2)} - \mu_i^{(k)})^2 + N(\sum_{i=1}^{n} \mu_i - 1)$$ (8)

And a partial derivative with respect to $\lambda_1$, $\lambda_1$, $N$ is taken to make

$$\begin{cases}
\frac{\partial L}{\partial \lambda_1} = 0 \\
\frac{\partial L}{\partial \lambda_2} = 0 \\
\frac{\partial L}{\partial N} = 0
\end{cases}$$ (9)

The matrix expression of the Lagrangian function optimization condition is:

$$\begin{bmatrix}
U^{(1)}(U^{(1)})^T + \lambda_2 U^{(1)}(U^{(2)})^T \\
(U^{(2)})(U^{(1)})^T + \lambda_2 U^{(2)}(U^{(2)})^T
\end{bmatrix}
\begin{bmatrix}
\lambda_1 \\
\lambda_2
\end{bmatrix}
= 
\begin{bmatrix}
U^{(1)}(U^{(1)})^T \\
U^{(2)}(U^{(2)})^T
\end{bmatrix}$$ (10)

The form of conversion into an equation is as follows:

$$\begin{cases}
\lambda_1 U^{(1)}(U^{(1)})^T + \lambda_2 U^{(1)}(U^{(2)})^T = U^{(1)}(U^{(1)})^T \\
\lambda_1 U^{(2)}(U^{(1)})^T + \lambda_2 U^{(2)}(U^{(2)})^T = U^{(2)}(U^{(2)})^T
\end{cases}$$ (11)

The values of $\lambda_1$, $\lambda_2$ are solved by the formula above, the secondary optimal combination of weight $U^* = (\mu_1^*, \mu_2^*, \cdots, \mu_n^*)$ can be gained.
Then mortality rate, birth rate, mining growth rate and other values that are difficult to get can be more accurately estimated to make the model more scientific by using this method.

Take mortality rate as an example, the calculation process and the results are as follows:

We have invited 12 experts to get 5 results by scoring: 3.50%, 4%, 4.50%, 5%, 5.50%, according to the favour numbers and specialization degree, two different weights could be calculated by statistical data of two indicators: \( \omega_1=(0.25, 0.17, 0.33, 0.08, 0.17) \) and \( \omega_2=(0.25, 0.19, 0.19, 0.22, 0.16) \), and then the calculation process above could help to obtain the optimal weight \( \omega_3=(0.23, 0.13, 0.46, -0.08, 0.16) \). And the final result is about 4.50% on the basis of maximum membership principle.

(3) There are some more subjective variables in the model, which should be dimensionless and standardized to establish the corresponding mathematical equations. First of all, the model has primarily benefit-type indicators whose property values are the greater the better; cost-type indicators whose property values of the indicators are as small as possible. In this paper, we first define the initial value of the benefit-type and cost-type indicator attribute is 1, then the attribute value is dimensioned and normalized by the linear change, and the process is as follows:

\[
\begin{align*}
\text{For benefit indicators: } z_i &= 1 + \frac{y_i - y_{\text{min}}}{y_{\text{max}} - y_{\text{min}}} \\
\text{For cost indicators: } z_i &= 1 - \frac{y_{\text{max}} - y_i}{y_{\text{max}}}
\end{align*}
\]

(12)

After that, the data are analyzed to find the regularity of data, thus the corresponding equation is obtained.

As the lack of data in Tibet, some of the variable data in the model is the estimated data. Among them, the horizontal variable data “land destruction area” of Tibetan area is missing, after several debugging, it is found that this variable has little influence on the operation of the whole model, so the system dynamic model is built without considering these variable for the time being.

4.2. Main mathematical equations in the model. The model contains dozens of mathematical expressions. Due to limited space, so some important equations in the model are listed.

Mineral resources subsystem:

(1) Added proven reserves=IF THEN ELSE(Time<2016, Added proven reserves for investment per unit*Mining investment, Added proven reserves for investment per unit*Mining investment*Impact factor of exploration influence);

(2) Annual added output=Annual output*Growth rate of mining*National mineral development policy;

(3) Mining capacity=Annual output/Proven mineral reserves;

(4) Mining investment=-194.304+0.443*Regional GDP;

(5) Mining output value=Output value for mineral per unit*Annual output

Economic development subsystem:

(1) Factors of GDP affected by supply-demand ratio=(Supply-demand ratio-0.98)/0.99+1.75;

(2) Increment of GDP=Regional GDP*Growth rate of GDP*Factors of GDP affected by supply-demand ratio;

(3) Output value of primary industry=Regional GDP*Proportion of primary industry in GDP;
(4) Regional GDP = INTEG (Increment of GDP, 507.46);
(5) Growth rate of GDP = IF THEN ELSE (Time < 2016, Table function of GDP growth rate, Table function of GDP growth rate * Education level * Speed of economic development * Growth policy of national economy);
(6) Mineral demand = Mineral demand of primary industry + Mineral demand of secondary industry + Mineral demand of tertiary industry;
(7) Mineral demand of primary industry = Output value of primary industry * Mineral demand of primary industry over 10,000 yuan in output value;
(8) Speed of economic development = 0.65 - (LN(Environmental pollution) / 10 - 1.35) / 2

Ecological environment subsystem:
(1) Discharge amount of solid waste = INTEG (Increment of solid waste - Variation of treated solid waste, 4.12);
(2) Discharge amount of wastewater = INTEG (Increment of wastewater - Variation of treated wastewater, 736);
(3) Discharge of exhaust fumes = INTEG (Increment of exhaust fumes - Variation of treated exhaust fumes, 15.81);
(4) Environmental investment = IF THEN ELSE (Time < 2016, 14.995 + Regional GDP * 0.027, (14.995 + Regional GDP * 0.027) * Policy of ethnic environmental improvement * Environmental awareness);
(5) Environmental pollution = Discharge amount of solid waste + Discharge of exhaust fumes + Discharge amount of wastewater;
(6) Increment of exhaust fumes = Mining output value * Variation of exhaust fumes for output value per unit;
(7) Increment of solid waste = Mining output value * Variation of solid waste for output value per unit;
(8) Increment of wastewater = Mining output value * Variation of wastewater for output value per unit * Mining output value

Social progress subsystem:
(1) Born population = IF THEN ELSE (Time < 2016, Total population * Birth rate, Total population * Birth rate * National fertility policy);
(2) Dead population = Total population * mortality rate; Education level = (LN (Disposable income per capita * 10000) / 8.8) / Cultural differences in ethnic areas;
(3) Factors of death rate affected by environmental pollution = LN(Environmental pollution) / 100 + 1;
(4) Mortality rate = IF THEN ELSE (Time < 2016, Table function of death rate, Table function of death rate * Factors of death rate affected by environmental pollution);
(5) Disposable income per capita = IF THEN ELSE (Time < 2016, Table function of disposable income per capita, Table function of per capita disposable income * Speed of economic development)

4.3. Model test.

4.3.1. Historic test. The data from 2010 to 2014 is selected and put into Vensim Dss 5.6a to complete the historic test, the results show that the errors between simulation value and real value are not more than 5 percent. It is generally believed that the simulation effect of the model is better for the real system if the relative error between the historical value and the simulation value is within 5 percent.
Therefore the model has resulted in high fit degree, in line with the actual situation, which can be used as a basis for prediction.

4.3.2. **Sensitivity test.** The sensitivity test is mainly to study the influence intensity of the system when the controllable parameter of a system changes in a small range. The influence of the same subtle change from different parameters on the system result is often different. Controllable parameters which influence the system result are called the sensitive factors. The sensitivity test is to verify the influence of the parameters on the behavior of the whole system, thus finding the sensitivity factors in the system. Sensitivity factors need to be accurately estimated, and insensitive parameters do not require repeated confirmation and scrutiny[6]. Due to limited space, some variables are selected, and discharge amount of solid waste is chosen to make sensitivity analysis. Figure 3 is the control parameters of policy of ethnic environmental improvement, respectively, on discharge amount of solid waste to do the sensitivity analysis map, and it is found that when the policy of ethnic environmental improvement changes, the discharge amount of solid waste are greater changes in the range, therefore, the policy of ethnic environmental improvement is a sensitive factor. After repeating sensitivity analysis, seven sensitivity factors have been identified, including impact factors of exploration influence, national fertility policy, national mineral development policy, impact factors of mining technology, cultural differences in ethnic areas, policy of ethnic environmental improvement and growth policy of national economy.

![Figure 3. Sensitivity analysis of policy of ethnic environmental improvement](image)

5. **Analysis and optimization of simulation results.**

5.1. **Design and analysis of four development modes.** In order to compare and explore the future development of Tibetan areas in different national fertility policy, national mineral development policy, national environmental remediation policy, national economic growth policy, the trends and circumstances of social and economic development, ecological environmental protection and mineral resources exploitation in Tibet will be discussed. According to the analysis above, the four
different development modes of Tibet region are designed by adjusting the main parameters of the MEES model in Tibet: Mode 1 is status quo maintenance type; Mode 2 is economic development type; Mode 3 is environmental priority type; Mode 4 is the economy-environment-resource-society coordination type. The parameters adjustment for four kinds of development modes is as follows: (See Table 3. And Pa=Parameters adjustment, Sqm=Status quo maintenance type, Ed=Economic development type, Ep=Environmental priority type, Eersc=Economy-environment-resources-society coordination type, Ie=Impact factors of exploration influence, Nd=National mineral development policy, It=Impact factors of mining technology, Nf=National fertility policy, Ce=Cultural differences in ethnic areas, Ge=Growth policy of national economy, Pe=Policy of ethnic environmental improvement)

| Pa | Sqm | Ed | Ep  | Eersc |
|----|-----|----|-----|-------|
| Ie | 1   | 1.1| 0.95| 1.05  |
| Nd | 1   | 1.1| 0.95| 1.05  |
| It | 1   | 1.1| 0.95| 1.05  |
| Nf | 1   | 1.1| 0.9 | 1     |
| Ce | 1   | 1  | 0.99| 0.99  |
| Ge | 1   | 1  | 0.95| 1.05  |
| Pe | 1   | 1  | 1.05| 1.05  |

Table 3. Parameters adjustment

5.2. Analysis of simulation results. According to the development ideas of the above four modes, the main parameters in the MEES model in Tibet are regulated, and the simulation operation model is realized. The simulation results of some state variables are shown in Figure 4, Figure 5, Figure 6, and Figure 7.

![Figure 4. The simulation result of Annual output](image-url)
Mode 1: Status quo maintenance type. All the control parameters are set to 1, according to the existing development scale and trend of the simulation, the forecast results show: from 2015 to 2030, the Tibetan area in the year detected mineral reserves would increase from 35.791 million tons to 89.364 million tons, causing an increase of 53.573 million tons, the average annual growth of about 3.5715 million tons, the annual output of mineral resources rising from 5.2988 million tons to 33.1406 million tons. At the same time, the GDP of Tibet would increase from 102.639 billion yuan to 461.558 billion yuan, and the total population would increase from 3.24 million to 4.4 million. The total discharge of waste water, waste gas and solid waste would increase from 6.957 million tons to 53.854 million tons.
Therefore, the development and protection of mineral resources, economic output, ecological and environmental protection and so on all need further to be improved in this development mode.

Mode 2: Economic development type. Adjusting the controllable parameters for the simulation, the forecast results show that the mineral reserves in Tibetan area would increase to 100.604 million tons in 2030. The annual output would increase to 45.1657 million tons in 2030, an increase of 12.0251 million tons compared with Mode 1. With the improvement of mining exploration technology, mining technology and the support of Tibetan policy, it would provide a strong guarantee for the development of mining and economy in Tibet, and promote the rapid growth of the local economy, GDP climbing to 530.864 billion yuan. Compared with Mode 1, the total GDP would increase significantly. Meanwhile, the total population of Tibet would increase significantly to 4.839 million in 2030, compared with Mode 1, and the total population of Tibet would increase more by nearly 0.439 million. However, the total discharge of waste water, waste gas, solid waste would increase to 81.7899 million tons, damaging the local ecological environment, so the mode could not meet the needs of sustainable and coordinated development in Tibet.

Mode 3: Environmental priority type. Adjust the controllable parameters to the simulation, the forecast results show that compared to Mode 1, Tibetan annual mineral reserves would increase to 85.1247 million tons, and the annual output would increase to 28.6297 million tons, and the speed of mining resources exploration and mining development utilization would slow down. GDP would increase to 441.685 billion yuan, and the population of Tibet would increase to about 4.003 million. GDP would be lower than Mode 1. The growing number of population in the region also would slow down. On the basis of ecological and environmental protection, the total emissions of waste water, waste gas and solid waste will be 30.9202 million tons by 2030, and compared to Mode 2, it would be a significant decline. However, in this mode, the development and utilization of resources and the speed of economic development would be a certain degree of hindrance and constraints. Therefore, this kind of environmental protection at the expense of the
economy is a contradiction to the vigorous development of economic policies in Tibet and is not suitable for the long-term development of Tibet.

Mode 4 of Economy-Environment-Resources-Social coordination type. By adjusting the controllable parameters to simulate the mode, the forecast results show that proven mineral reserves would increase to 95.7659 million tons, the annual output of mineral resources would increase to 38.5827 million tons, and the two values will be between Mode 2 and Mode 3, but they will be higher than Mode 1. The regional GDP would increase by 50.7554 million, compared to Mode 1 increased by nearly 45.996 billion yuan, and the regional population of 4.404 million people would be almost flat with Mode 1. During the period of developing economy, ecological environment governance and maintenance should be focused. Waste water, waste gas, solid waste and three waste totals of 52.9215 million tons would be lower than Mode 1 of about 0.9426 million tons, not only would not rise but also would show a slow decline in the trend. has been revised to GDP per capita of about 115.2 thousand yuan, an increase of nearly 10 thousand yuan than Mode 1, residential quality of life would be further improved. In this mode, not only the effective development of mineral resources should be taken into account, but also the associated ecological environment governance should be considered, so the ecological environment at the expense of mining would not happen; not only we pay attention to the steady development of economy, but also focus on the improvement of residential quality of life and social progress. Therefore, this is the best mode for the future development of Tibet in the kind of mode under the best development plan.

6. Conclusion. In this paper, the MEES system conforms the minority areas in China which is constructed by using a dynamical system. Taking Tibet as an example, the simulation is carried out to predict the situation in Tibet in 2030. And four different development modes are designed. According to the four-simulation data of development mode, we can see the mode to achieve the sustainable development in Tibet, we should ensure the increase in mineral resources development for regional economic and social development, as well as pay a attention to the local ecological environment protection, local waste water, waste gas, solid waste and other pollutants emissions that should be reduced, making the coordination in development of Tibetan mineral resources, society and economy. Mode 4: Economy-Environment-Resources-Society coordination, the annual mining resources of mineral resources would increase by 5.4421 million tons in 2030, and the population in the area is almost the same as Mode 1. The regional economy would increase by 45.996 billion yuan. However, the total amount of waste water, waste gas and solid waste would be lower than Mode 1 about 0.9426 million tons, can be seen that in the mode of economic and mining development, and the environment could not be further deteriorated but get a certain treatment. Therefore, Mode 4 is more suitable for the future development trend of Tibet. Due to the limitation of subjective and objective conditions, and the difficulty of data acquisition, the model and its accuracy would be further researched to keep a perfect state.

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