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Research on dynamic measurement of environment cost of coal resource development

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ABSTRACT

In accordance with the thought of internalization of external costs and feedback control relationship among environmental damage variables during the development of coal resource, the research employs system dynamics method to establish SD model for dynamic measurement of environment cost of coal resource. In this research, the SD model is put into specification and application research with help of compensation case related to environmental damage in Shanxi province.

KEYWORDS

Environment cost; Dynamic measurement; SD model.

MEASUREMENT OF ENVIRONMENTAL TREATMENT COST DURING THE DEVELOPMENT OF COAL RESOURCE

Treatment and compensation for mining subsided area

Treatment and compensation for mining subsided area mainly include the following fees: compensation for reduced crop yield within the subsided area due to coal mining, land resource loss within the area, compensation for damaged building due to land subsidence, compensation for relocated residents within the subsided area and treatment cost for restoring the subsided area to farmland.

1) Compensation for crops within the subsided area is calculated as followings.

$$T_1 = L \times f \times g \times v_1 \times 5 \quad (1)$$

Where, T_1—compensation for crops within mining subsided area, L—raw coal yield, f—mining subsidence coefficient, g—proportion of farmland in subsided area, v_1—yield of crop per hectare. Compensation for reduced or failed crop yield shall be paid for at least five years as per average level in the locality.

2) Compensation for land resource loss within subsided area is calculated as followings.

$$T_2 = L \times f \times h \times v_2 \quad (2)$$

T_2—compensation for and resource loss within mining subsided area, L—raw coal yield, f—mining subsidence coefficient, h—proportion of failed farmland in subsided area, v_2—expropriation price of subsided farmland per hectare.

3) Compensation for damage to ground facilities due to mining subsidence is calculated as followings.

$$T_3 = t_1 + t_2 + t_3 \quad (3)$$

T_3—compensation for damage to ground facilities due to mining subsidence, t_1—compensation for damaged building per ton of coal, t_2—compensation for damaged transportation facilities per ton of coal, t_3—compensation for damaged hydraulic facilities per ton of coal.

4) Compensation for relocated residents is calculated as followings.

$$T_4 = R \times h \times v_3 \quad (4)$$

T_4——compensation for relocated residents; R——population affected by mining practice of coal resource, h——proportion of relocated population within the affected population, v_3——allowances paid to each relocated person.

5) Treatment cost of mining subsided area is calculated as followings.

$$T_5 = 15 \times L \times f \times (g \times v_4 + j \times v_5) \quad (5)$$

T_5—treatment cost of mining subsided area, L—raw coal yield, f—mining subsidence coefficient, g—proportion of farmland in subsided area, j—proportion of land for other purposes exclusive of farmland and land for construction and transportation in subsided area, v_4—treatment and restoration cost of subsided farmland per mou, v_5—treatment cost of grassland and forest land per mou for basic period extended to 15 years.

Discharge and treatment cost of gangue

Gangue, solid waste discharged during coal mining and washing process, is a charcoal grey colored rock which is, harder than coal but having lower carbon content, formed during coal formation process and closely mixed with coal. Gangue includes gangue selected during coal washing process and that mined during wall driving and from the coal seam between the roof and the floor. Gangue is mainly composed of Al_2O_3 and SiO_2 with different amount of Fe_2O_3, CaO, MgO, Na_2O, K_2O, P_2O_5 and SO_3 and trace elements inclusive of gallium, vanadium, titanium and cobalt. Related statistics show that approximately 14 million tons of gangue could be produced in China for each 100 million coal produced, accounting for over

40% of total solid industrial waste discharged in China. China possesses over 3,000 gangue mountains at present, giving total stock of gangue up to 4.6-5 billion tons. The land occupied by the gangue mountains totals 6.5×10^4hm^2 in area at present and this number continues to rise every year. Stockpiling gangue in large quantity not only occupies land but also affects ecological environment. Leaching water from gangue could pollute surrounding soil and underground water. Gangue which contains certain amount of combustible materials could ignite spontaneously in suitable conditions, emitting harmful gas as sulfur dioxide, nitrogen oxide, oxycarbide and fume, polluting environment and affecting local residents' health.

Discharge and treatment cost of gangue include land occupation charges, gangue discharge and treatment fee.

1) Land occupation charges could be calculated by following formula.

$$M_1 = L\times g\times z\times d\times v_6 \quad (6)$$

M_1—land occupation charges due to gangue discharge, L—raw coal yield, g—proportion of overall discharge of gangue in coal mines, z—average land area occupied by each ton of gangue, d—proportion of stockpiled and newly discharged gangue, v_6—average compensation for occupied land due to stockpiling of gangue.

2) Pollutant discharge fees for newly increased gangue could be calculated as followings.

$$M_2 = 5\times L\times g\times d \quad (7)$$

M_2—pollutant discharge fees for newly increased gangue, L—raw coal yield, g—proportion of overall discharge of gangue in coal mines, d—proportion of stockpiled and newly discharged gangue. In accordance with Standards and Regulation Rules for Collecting Pollutant Discharge Fees of National Development and Reform Commission of China, pollutant discharge fees of stockpiling of newly increased gangue shall be 5 Yuan/ton.

3) Treatment fee for discharged gangue could be calculated as followings.

$$M_3 = L\times g\times b\times v_7 \quad (8)$$

M_3—treatment fee for discharged gangue, g—proportion of overall discharge of gangue in coal mines, b—proportion of treatment cost for stockpiled and newly discharged gangue within treatment cost of raw coal, v_7—coal treatment fee per ton.

Gangue treatment refers to extinguishing of spontaneously ignited gangue and classification, selection and treatment of gangue. In accordance with Criteria for Pollutant Discharge of Coal Industry of National Environment Protection Bureau of China, permanent stockpiling site for gangue is prohibited and newly increased gangue shall either be utilized or treated.

Discharge and treatment cost of mine water

Discharge and treatment of mine water mainly include discharge and treatment project of mine water and prevention and treatment of degraded soil quality due to water resource loss resulting from mining and other work. The work excludes pollution to and loss of water resource.

a) Discharge fee of mine water could be calculated as followings.

$$K_1 = L\times p\times v_8 \quad (9)$$

K_1—discharge fee of mine water, L—raw coal yield, p—proportion of discharged mine water during mining of coal resource, v_8—criteria for collection of mine water discharge fee.

Mine water is produced in large volume during coal mining process and in the case that mine water is of high quality and satisfying criteria of national and local government, the discharge fee could be as low as 0.5 Yuan/ton; otherwise, the discharge fee shall be calculated as per regulations on sewage discharge. The fee could be doubled with mine water quality exceeding pollution equivalent. In normal circumstance, the pollutant discharge fee is levied on the basis of 0.7 and 1.4 Yuan/ton respectively with mine water quality within or beyond pollution equivalent.

b) Mine water treatment fee

Mine water discharged during coal mining activities could be utilized after treatment with help of related treatment technology for industrial and irrigative purposes. As statistics of China's key coal mines in 2005 reveal, state owned mines produced 919 million tons of coal in 2005, producing mine water totaling 1 billion tons. Supposing 50% mine water, totaling

500 million tons, exceeds related criteria and needs to be treated, total investment and operation fees could reach 780 million and 240 million Yuan respectively, giving treatment cost of mine water amounting to 0.25Yuan/ton.

Coal mining could inevitably lead to leakage of underground water and decline of ground water, resulting in degraded soil quality. This is especially true of China's western region which is endowed with rich coal resources but has highly fragile ecological environment. For the objective of preventing degradation of environment, discharged mine water shall be utilized for drip and sprinkling irrigation to improve ecological environment. Investment and operation cost of advanced water saving irrigation technology average 22,500 Yuan per hectare and 600 Yuan per ton respectively. Supposing coal companies irrigate goaf for five consecutive years, the irrigation cost of mine water could be 0.35 Yuan/ton approximately.

Hence, it could be calculated that discharge and treatment cost of mine water per ton of coal totals 1.61 Yuan/ton.

Calculation of costs of environmental damages by gas pollutants

Air pollution exists in different stages of development of coal resource. For instance, waste gas is produced and causes considerable pollution during the mine exhaustion, spontaneous ignition of gangue and ventilation of gas inside coal seam and of fume from boilers at site. In addition, dust is produced during transportation and storage of coal, which causes pollution. Hence, while establishing model for calculating costs of environmental damage by gas pollutants, cost per unit volume of environmental damage from waste gas of particular density C_P together with basic density shall be taken as the basis to calculate cost of pollution by gas pollutants of different density.

$$F_p = \begin{cases} 0 & P < P_0 \\ \dfrac{P}{P_0} \times F_{P_0} & P \geq P_0 \end{cases} \tag{10}$$

Where, P —density of pollutants; P_0 —basic density of pollutants; F_{P0} —costs per unit volume of environmental damage from waste gas of basic density P_0.

Costs per unit volume of environmental damage from waste gas of basic density, F_{P0} could be calculated with reference to related environmental pollution data.

In the case that there exist different pollutants, expert guidance could be utilized to analyze relation among different pollutants and weighting method be adopted to calculate air damages by different pollutants. Hence, model for calculating costs of overall environmental damage by gas pollutants could be established as followings:

$$F_q = \sum F_p^i \times \lambda_i \times V_i \tag{11}$$

Where, F_q —costs of overall environmental damage by gas pollutants; F_p^i —costs per unit volume of environmental damage from waste gas of category i; λ_i —conversion ratio for pollutant of category i; V_i —volume of pollutant of category i.

Measurement and calculation of costs of treatment of noise pollution

Mining site could cause noise pollution to surrounding environment during the development of coal resource. The issue of measurement and calculation of cost of treatment of noise pollution is a current research topic for domestic and international scholars; whereas, a mature treatment model is still not yet formed. Standards for collecting noise emission fees are listed in the TABLE 1 below.

TABLE 1 : Fee standards of noise emissions

Decibel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Fee standards (Yuan/month)	350	440	550	700	880	1100	1400	1760
Decibel	9	10	11	12	13	14	15	16及16以上
Fee standards (Yuan/month)	2200	2800	3520	4400	5600	7040	8800	11200

ESTABLISHMENT OF SD MODEL FOR DYNAMIC MEASUREMENT OF ENVIRONMENT COST OF DEVELOPMENT OF COAL RESOURCE

Based upon analysis of effects of development of coal resource on environment and environment cost of treatment of environment pollution therefrom, in accordance with the thought of internalization of external costs, techno-economic appraisal theory and feedback control relationship between environment cost elements and environmental costs of coal resource, the research employs system dynamics theory and method to conduct in depth analysis of environment elements, which is detailed in Figure 1 below.

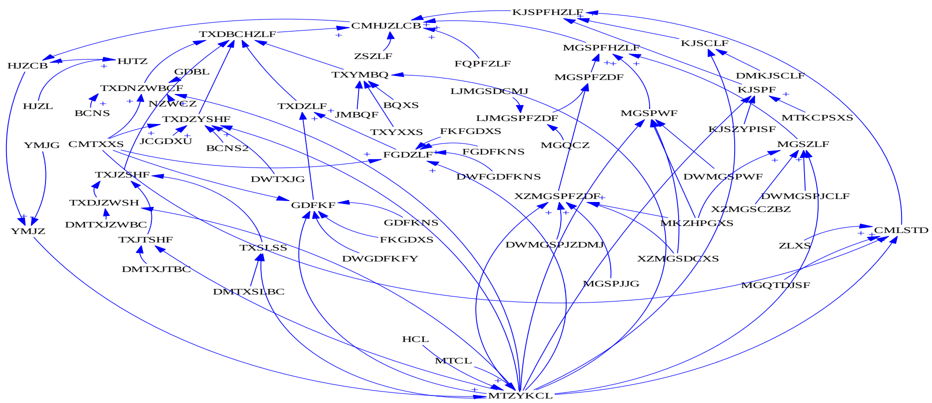

Figure 1 : Relation between elements of environment cost

SD flow chart to clarify environment cost of coal resource and coal production is shown in Figure 2 below based upon casual relationship figure here above.

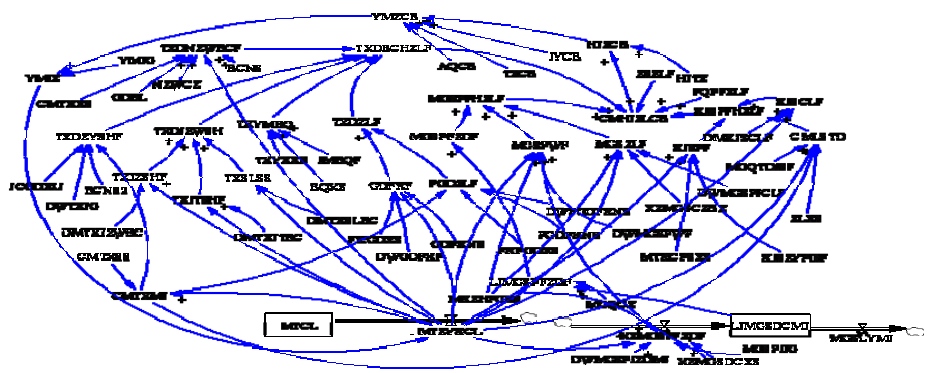

Figure 2 : System flow chart of environment cost

CASE ANALYSIS

In accordance with feedback control relationship among environmental damage variables during the development of coal resource, the research employs system dynamics method to establish SD model for dynamic measurement of environment cost of coal resource. In this research, the SD model is put into specification and application research with help of compensation case related to environmental damage in Shanxi province.

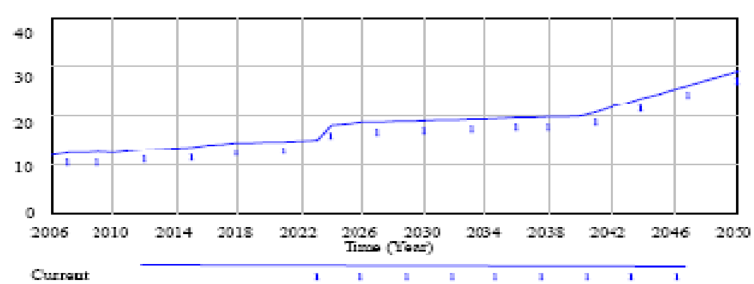

Figure 3 : Change map environment costs per ton of coal

CONCLUSIONS

The simulation figure demonstrates clearly that environmental cost of development of coal resource in Shanxi province tends to rise with increasing raw coal yield and that coal reserve in Shanxi province declines with increasing coal mining activities therein. With help of related data and system dynamics model, data of cost for treating environmental pollution during development of coal resource in Shanxi province in particular year in the past could be calculated and anticipations could be generated thereupon as well. Take the year of 2006 as an example. Compensation for and treatment of mining subsided area for every ton of coal mined in Shanxi province in 2006 is calculated to be 6.12Yuan/ton, gangue discharge and treatment fee for every ton of coal mined therein calculated to be 4.98Yuan/ton, noise nuisance fee to be 0.01 Yuan/ton and waste gas emission fee could be neglected due to difficulty in collecting data. Based upon information here above, it could be concluded after calculation of costs of treatment of environmental pollution that external loss of Shanxi province due to coal mining practice could amount to 12.72 Yuan/ton each year.

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