Simulation of the Spatial-temporal Evolution of Coal Supply and Demand Based on Multi-agent

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Simulation of spatial-temporal evolution pattern of coal supply and demand is important for a variety of planning and management issues as well as for academic research. However, Coal resource supply and demand system is an interaction of multiple factors, natural, economic and social complex spatial-temporal dynamic and complex process. There are numerous studies on coal supply and demand of spatial-temporal evolution (CSDSE) using the time sequence of energy supply and demand and the relationship with economic development [1~12]. However, there is a general lack of studies on the simulation of CSDSE because of their complexities. It is possible to project future coal supply and demand patterns using empirical data, and the generic paths of change can be identified. It cannot provide the seer, scientific guidance for the individual coal supply-demand Agent, and lack of the CSDSE of process, cause explanation.

To overcome those difficulties and seek well-distributed alternatives, this paper presents a new method to simulate the patterns of CSDSE based on the bottom-up approaches, agent-based models (ABMs) using GIS. Simulation of the patterns of CSDSE using ABMs is difficult because numerous spatial variables and parameters have to be utilized. Conventional ABMs models have problems in defining simulation parameter values and model structures. In this paper, a two-layer multi-agent with decision-making behavior model ①② is designed to calculate the coal transportation probabilities for competing multiple coal supply and demand Agents. The model involves Dynamic Random Utility Model [13] and Discrete Choice Model [14] to simulate the coal supply and demand decision processes. The GIS is used to obtain site attributes and environmental factors data, and to provide spatial functions for constructing the decision-making behavior model. The parameter values for modeling are automatically generated by the Entropy Weight Method. The agent-based model can well simulate complex natural systems that are influenced by both human and social factors [15~17], and provide a useful model framework to represent multi-stakeholders and catch the interactions among them. By changing the structure of the model and input parameters, to simulate the spatial-temporal evolution pattern of the coal supply-demand under different environmental factors, from a new perspective reveals the CSDSE of the differentiation process and its causes, through the regulation of the environmental factors, the macro decision-making can choose the ideal development model of supply-demand of coal resources, and provide decision support for sustainable utilization of coal resources, and provides a new train of thought to study spatial-temporal evolvement in the coal supply and demand pattern.

①The coal suppliers Agent decision-making behavioral model

Assume the coal suppliers agent seek the maximum benefits, combined with Dynamic Random Utility Model, research the internal mechanism of suppliers Agent choose customers decision behavior. The candidate spatial location of the customers L_{ij} for the supplier Agent of location utility can be expressed with the following formula:

$$U(t,ij) = a \cdot C_{production\_cost} + b \cdot C_{type\_price} + c \cdot C_{storage\_cost} + d \cdot C_{\text{Transportation\_cost}} + \varepsilon_{ij} \quad (1)$$

$$C_{\text{Transportation\_cost}} = C_{water\_cost} \cdot D_{water} + C_{railway\_cost} \cdot D_{railway} + C_{highway\_cost} \cdot D_{highway} + \psi_{ij} \quad (2)$$

Where, $a+b+c+d=1$,$C_{production\_cost}$, C_{type_cost} , $C_{storage\_cost}$, $C_{transportaion\_cost}$ are unit coal production price, coal unit price, unit coal storage cost, delivery to the customer destination L_{ij} transportation price; a、b、c、d are unit coal supplies weight coefficient; ε_{ij} is random disturbance term; C_{water_cost}, $C_{railway\_cost}$, $C_{highway\_cost}$ are the supplier Agent (t) transport unit coal to the customer destination L_{ij} every kilometers waterway freight, every kilometers railway freight and every kilometers highway freight; D_{water_cost}, $D_{railway\_cost}$, $D_{highway\_cost}$ are the supplier Agent (t) transport unit coal to the customer destination L_{ij} through waterway transport distance, railway transport distance and road transport distance; ψ_{ij} is the delivery process of random perturbation term.

② The coal demanders Agent decision-making behavioral model

As a rational demanders, different types of consumers because of its own economic and social properties of difference and performance of the coal price affordability of difference, which showed decision-making behavior from different spatial position of suppliers. A spatial location L_{mn} coal demanders Agent in the first k years can pay the u kind of coal unit price can be expressed with the following formula:

$$P(k,mn) = \frac{w \cdot GDP \cdot (1+r_k) \cdot CCP \cdot s_k \cdot u}{CC \cdot v} \quad (3)$$

Where, W is L_{mn} spatial position demanders energy costs accounted for the proportion of GDP, GDP is the L_{mn} spatial position the overall size of the economy, r_k is the L_{mn} spatial position the k annual economic growth rate, CCP is L_{mn} spatial position of coal accounted for the proportion of energy-consuming, s_k is technological progress reduce the coal energy consumption ratio, u is the u kind coal consuming accounted, CC is the L_{mn} spatial position of total coal consumption. v is the L_{mn} spatial position the u kind of coal consumption accounted.

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