

Research on the Coal Logistics Network's Property Based on the Complex System Theory of Supply Chain

Lijun Liu¹, Xiaoji Guan¹

¹ College of Management Science and Engineering, Shandong Institute of business and technology, Yantai 264005, Shandong china

llj2002-1@163.com

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Abstract. This article puts forward the practical significance of studying the complex characteristic of coal logistics network from the coal resource effective utilization and rational allocation. According to the characteristics of coal enterprises, the coal logistics network is defined as the complex network system. Based on the complex system theory of the supply chain, the coal logistics network is analysed separately from the complexity of node and structure, the small world property as well as the scale-free property and it is pointed out that the coal network has complex network structure, the small world property and the scale-free property.

Introduction

Coal is an important basic energy in China in the structure of the primary energy production and consumption, its corresponding proportions are 76% and 69% and it will play an irreplaceable role in the long run. According to statistics the total coal output in China amounted to 2.716 billion tons in 2008 increasing by 0.193 billion tons. In recent years the coal industry in China has shown great enthusiasm for the coal logistics researches, many logistics modes such as the different level and type of the coal logistics center, the coal distribution center, the port storage and transportation center have already appeared and logistics is bringing visible profit for these enterprises. Thus, most large coal enterprises attach great importance to the coal logistics integration, developing, research, at the same time the academic circle also takes it seriously with publishing lots of papers related to the coal logistics. However in all current research results the problem about the coal logistics network's characteristics is still lack in thorough research. The structure of coal logistics network is complex which has great influence on the coal resource's efficient utilization and reasonable flow. Therefore in order to promote the optimal allocation and effective use of coal resources in China to achieve smooth flow it is necessary to strengthen the research and promotion of the coal logistics network. Of course it will ease the energy tension and has important significance of promoting the development of the national economy.

The connotation of the coal logistics network

The coal production has its own characteristics: large amount of decentralized nodes (coal mine), the relatively far distance between the producing area and the users, a combination of multiple transportation (such as highway-railway-waterway combined transport) to finish the transport. Obviously the coal logistics network is a complex supply chain system with multiple nodes and links (edges). Based on the complex system theory we regard the supply chain as a complex network which is made of a series of entities for any two entities, one is the upstream, the other is downstream firm. So the coal supply chain is a solid network system which is made of coal mine entities distributed in different regions, the upper inventory related to the coal production and the users in the downstream[1]. The coal logistics network is the tie of realizing these material's reasonable flow and configuration while the materials are coal resources and necessary materials for coal producing and to realize functions it needs to use different nodes of the network. Here the coal logistics node refers to the areas where there gathers coal facilities and provides the service for the coal logistics including coal port, freight yard, logistics park with such functions-- trade, transport, processing and

distribution as well as information processing. In western China there exist rich coal resources with well-found species and large output. Coupled with high quality resources, good infrastructure the more flourishing external environment of transport condition and the region advantage combined the west with the whole country, now it is constructing large coal logistics parks and distribution centers in western China which is responsible for more than 200 coal mine's distribution, processing, trading and distribution in Erdos city aimed at making Erdos become an important coal logistics center and the national coal trading center. The coal network structure is illustrated in Fig. 1.

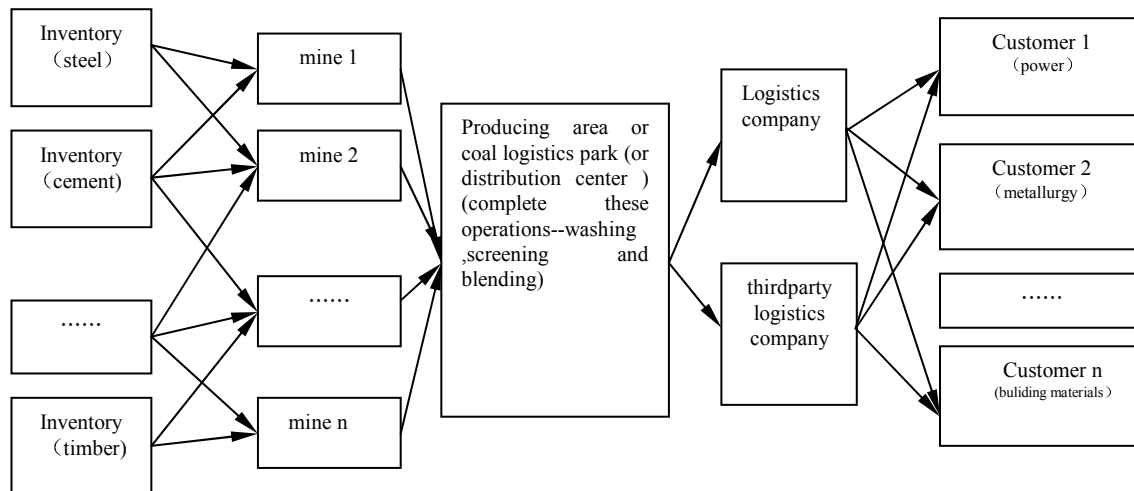


Fig.1 The coal logistics supply chain network structure diagram

From the figure 1 we can see there are some differences in the organization of the operating pattern between the coal logistics network manufacturing logistics network:

(1) The coal supply chain is an apparently closed circular structure. In the universal manufacturing enterprises, although the supply chain closure phenomenon also exists in general its closure phenomenon is accidental and random; While in the coal supply chain the building materials, the machine and the power are the main user who consume the coal products meanwhile they are inventories of the coal groups' main materials too. This kind of mutual supply relationship has determined the necessity of the ring-linked close of the coal supply chain[1,2].

(2) To coal supply chain its structure is simple however to manage it is too difficult. Compared with the universal manufacturing industry coal production doesn't have intermediate products and the consumption of the materials do not form the part of the product entity and the production chain is relatively short. The supply chain structure is relatively simple but once from the point of management the supply chain management is complex which means that the coal enterprise has a large number of inventories(generally, a large coal group involves thousands of inventories), numerous kinds of consumption materials (more than ten thousand) even large amount of wasted logistics such as gangue[3].

(3) The single characteristic of coal products energy type makes the users focus on the quality stability and the reliable output other than the coal products' quick respond.

(4) The bottleneck of coal logistics network is how to realize the smoothly transportation. On the one hand the users reflects the shortage of coal resources, on the other hand there are a large number of stocked coal. When investigated we conclude that the fundamental reason is transport tension especially the railway transportation can't meet the demand. In recent years, our country has built a substantial expressway, highway while the railway construction still does not have big breakthrough. At present some large enterprises has put forward plans to build the railway and harbor. Such as the Datang group puts forward the pre-feasible research of the line from the Erdos city to Jingtang port; Inner Mongolia Pearl River Investment Limited Company puts forward the pre-feasible research of the new-bulit railway from Zhungeer to Shuzhou; Inner Mongolia Yitai group proposes the project research report about the railway construction from Datong to Dongsheng; Shenhua group and

Huaneng group are also active in planning projects about the railway construction and the port construction. If these projects acquire the approving of construction it will relieve the tense situation of the coal resource's transport[4].

(5) The stock of the coal enterprise is special. Different from the universal manufacturing industry the coal production process is usually affected by natural conditions and it exists many uncertain factors and requires a higher measurement of safety protection. All this determine that to the special materials and machines that used in the coal production we can not carry out zero inventory to control it.

The complexity of the coal logistics network structure

Generally, from the composition of the network it includes two basic elements namely the node and the edge that connects the node. The node is used to express each member enterprise in the network and the edge is used to describe the relationship of each enterprises. The complexity of the coal logistics network structure is mainly expressed in the following aspects:

(1) The complexity of node. With the rapid development of the global economical integration the supply chain network no longer covers a region and a country and many large coal enterprise have already set up multinational global supply chain network system. For example, the Dingfeng logistics company which once belonged to the Fengfeng group whose business is already in shanxi ,shangdong, henan, jiangsu and Inner Mongolia nearly 20 provinces(city, region). Its business scope changes greatly in the past it simply provided service for the coal enterprises but now it has extended its business to more than ten fields such as the steel field the building materials field and the wire cable field etc. In February 2007, the group established Shangdong Rizhao Fengfeng Limited Company in Rizhao, shangdong. It mainly develops import-outport business and wants to realize the grand goal—"We can buy and sell the products all around the country even all around the word. So it is so easy to imagine that the whole supply chain structure will be more complicated when each node enterprises in the supply chain have complicated structure. When we study the supply chain network it is hard to simply abstract the node enterprise for a point on the contrary we must give it a lot of properties. In addition, because of the differences of main factors such as the target of management, corporation culture and market position the behavior of each node enterprises is different what's more each enterprise has autonomy characteristic[5].

(2) The complexity of the edge. The connections between the nodes enterprise not only represent whether they have relationships, moreover they may involve other relationships such as competition, cooperation and game, etc. The connections between the nodes can be relatively stable can also be a one-off cooperation even it can be a period cooperation relationship. With the expansion of the network, the number of nodes is continually increasing and the connections between the nodes are also increasing. At the same time usually the node itself is behavior subject whose behavior will keep changing. What's more different nodes have different characteristics. In addition the direction of the side is not one-way either. For instance, the logistics involves forward logistics and reverse logistics.

(3) The complexity of the environment. The nodes in the logistics network interact with each other, at the same time there exists mutual influence with other supply chain entities and they interact and affect their own behavior pattern in a complicated way with dynamically manifesting the reengineering and replacement of the supply chain. In addition the market environment, the policy and regulations and the incident, etc, also affects the coal supply chain. In mid-january 2007 in China we experienced a rare snow and ice storm which lead to power outage and traffic trouble. Coupled with some coal mines having a holiday ahead of time or a maintenance all the above badly affected the coal supply[6]. The coal stock of some power plant descended sharply which caused 19 provinces (region, city) in the whole country to pull a restriction of electricity and the normal production as well as the daily life order was greatly disturbed.

From the above we can see the coal logistics network has complex network characteristics and its dynamic changes will have great influence on the coal supply chain. In the following we will analyse the coal logistics network separately from the small world property and the scale-free property.

The coal logistics network's small world property

The coal logistics network has small world property namely the small average path length and the high clustering coefficient. In the network we have such assumes:

d_{ij} = distance between node i and node j

L = average distance between any of two nodes or network feature path length

n = number of the nodes

thus, we can obtain:

$$L = \frac{1}{2n(n+1)} \sum_{i \geq j} d_{ij} \quad (1)$$

Clustering coefficient is a kind of parameters which is used to exclusively measure the condition of the nodes clustering. For example in the enterprise network the downstream customers may also be your direct customers; Two upstream inventories are likely to supply each other. Clustering coefficient is used to measure the network's such nature.

Generally suppose the node i has k_i edges in the network, and connect it with other nodes, these k_i nodes are called the neighbors of node i . Apparently, there may be $k_i(k_i-1)/2$ edges at most among these k_i nodes. And the ratio of E_i that the edges actually exists among the k_i nodes and $k_i(k_i-1)/2$ possible existed is defined as the Clustering coefficient C_i of node i , we can obtain:

$$C_i = \frac{2E_i}{k_i(k_i-1)} \quad (2)$$

C_i = Clustering coefficient of node i

E_i = the edges actually exists among the k_i nodes

k_i = the number of nodes connected with node i

The whole network clustering coefficient C is the average value of all node i clustering coefficient C_i .

In the coal logistics complex network we can use average path length L to express the time of the raw materials or products and use average Clustering coefficient to express the relationship's degree of the node enterprise in the chain[7]. The enterprises at the nodes of the coal supply chain through mutual functional integration set up the distribution center and reduce the coal transportation distance so as to better achieve timely supply. For example, through constructing large-scale coal logistics park and distribution center Ordos city focuses the coal that scattered in 276 local mine in the city on a few large distribution center for washing, screening, and blending of processing operations so that it produces the exact coal product to meet different customers needs then does the coal distribution business by developing highway and railway network. So we can find out that the coal logistics supply chain network has smaller average path length. Each node enterprises in the coal supply chain usually have aggregation property. For example, prior to coal enterprises' reforming some logistics company is a department or subsidiary. After reengineering they depart from the company and even some node entities are cross-ownership. In addition more and more coal logistics enterprises use the information technology (such as EDI, ERP, etc) through the Internet to the nodes establish the connection between each other through sharing the information the node enterprises are becoming closer and communicate more frequently which also show that the coal logistics supply chain network has high accumulation coefficient.

The coal logistics network's scale-free property

The coal logistics network also has the scale-free property, that is to say, the network exists such node whose node degree is large. In many past empirical researches people find that the real network node degree obeys power-law distribution, a node degree is the number of adjacent node owed by the node

or the number of edge associated with the node. That node degree obeys power-law distribution means that we can use a power function to approximately express the relationship between the node's number whose degree is certain and the certain node degree. The power function curve descends slowly and it makes the node whose degree is large exists in the network. In this sense the network whose node degree obeys power-law distribution is called the scale-free network and we call such node degree's power-law distribution the network's scale-free property.

In the coal supply chain it usually has a core enterprise, generally it is a large coal producing group through the Internet the core enterprise establish a close contact with other node enterprise such as the building materials producer, the cement producer, the steel producer, and around the core coal production enterprise, it sets up the supply-producing-distribution system and all the above reflect the coal supply chain network's scale-free property. At the same time, many more enterprises join the supply chain and they will choose to establish business relationship with the core enterprise which also reflects the supply chain scale-free network's growth property. In addition the coal logistics distribution center deliver the coal to each customer warehouse also reflects the coal logistics network scale-free property. In recent years, the third party logistics based on the information service provides the comprehensive supply chain solution through coordinating the coal supply chain and optimally allocating the management and technology of the coal supply chain, etc, and integrates the coal supply chain system. It is a hub that provides exchange and connection for the node enterprise in the supply chain and it is also equivalent to key node of high node degree in the scale-free network.

Conclutions

To sum up the coal resource in China's energy policy occupies a key position which effectively supports the sustainable development of the national economy. According to the data prediction by 2050 the proportion of the coal resource still maintains above 10% in the energy consumption.

Therefore in the future considerable long a time the coal resource is still one of importance mainstay industry in China's energy.

At present in the development and utilization of the coal resource in China the waste of the coal resource and the effective allocation have become increasingly prominent and it will bring forward challenge to the sustainable development of the economic society. The purpose of studying the complexity of the coal logistics network is to realize the effective distribution of the coal resource and the rational utilization, and is of realistic significance in guaranteeing the national energy security and promoting rapid and sound development of the economic.

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